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THERAPEUTIC COMPOSITIONS THAT ALTER THE IMMUNE RESPONSE

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Technical Field

The invention concerns methods and compositions having increased therapeutic effect by altering the immunogenicity of the active component without decreasing the active component's antigenicity. Typically, a beneficial therapeutic effect is derived from altering the state of the immune system, and for some embodiments of the invention, e.g., cancer immunotherapy, immunogenicity is induced, activated, or increased. The invention also concerns methods and compositions for stimulating a host's immune response, particularly for the treatment of cancer. The methods and compositions according to the invention use binding agents such as antibodies to generate an immune response to a pre-determined antigen.

Background Art

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In vertebrates, the mechanisms of natural and specific immunity cooperate within a system of host defenses, the immune system, to eliminate foreign invaders. The hypothesis that the immune system ought to be able to recognize tumors and thus could be recruited in the fight against cancer has been a driving force behind outstanding efforts of many immunologists. This approach is attractive because of the

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1 unique ability of the immune system to specifically destroy affected cells while
mostly sparing normal tissue. Moreover, the initial immune response is known to
leave behind a long-term memory that serves to protect from the same disease in the
future. No drug treatment for cancer can claim such specificity or memory.

5 An immunotherapeutic strategy for the treatment of cancer and other diseases
or conditions involve one or more components of the immune system to trigger a
complex cascade of biological reactions focused on eliminating a foreign molecule
from the host. Vertebrates have two broad classes of immune responses: antibody
9 responses, or humoral immunity, and cell-mediated immune responses, or cellular
immunity.

Humoral immunity is provided by B lymphocytes, which, after proliferation
and differentiation, produce antibodies (proteins also known as immunoglobulins)
that circulate in the blood and lymphatic fluid. These antibodies specifically bind to
the antigen that induced them. Binding by antibody inactivates the foreign
substance, e.g., a virus, by blocking the substance's ability to bind to receptors on a
target cell or by attracting complement or the killer cells that attack the virus. The
humoral response primarily defends against the extracellular phases of bacterial and
viral infections. In humoral immunity, serum alone can transfer the response, and
the effectors of the response are protein molecules, typically soluble, called
antibodies. Lymphocytes produce these antibodies and thereby determine the
specificity of immunity; it is this response that orchestrates the effector limbs of the
immune system. Cells and proteins, such as antibodies, that interact with
lymphocytes play critical roles in both the presentation of antigen and in the
mediation of immunologic functions.

25 Individual lymphocytes respond to a limited set of structurally related
antigens. As noted in more detail below, this function is defined structurally by the
presence of receptors on the lymphocyte's surface membrane that are specific for
binding sites (determinants or epitopes) on the antigen.

29 Lymphocytes differ from each other not only in the specificity of their
receptors, but also in their functions. One class of lymphocytes, B cells, are

precursors of antibody-secreting cells, and function as mediators of the humoral immune response.

Another class of lymphocytes, T cells, express important regulatory functions, and are mediators of the cellular immune response. The second class of immune responses, cellular immunity, involve the production of specialized cells, e.g., T lymphocytes, that react with foreign antigens on the surface of other host cells. The cellular immune response is particularly effective against fungi, parasites, intracellular viral infections, cancer cells and other foreign matter. In fact, the majority of T lymphocytes play a regulatory role in immunity, acting either to enhance or suppress the responses of other white blood cells. These cells, called helper T cells and suppressor T cells, respectively, are collectively referred to as regulatory cells. Other T lymphocytes, called cytotoxic T cells, kill, for example, virus-infected cells or tumor cells. Both cytotoxic T cells and B lymphocytes are involved directly in defense against infection and are collectively referred to as effector cells. There are a number of intercellular signals important to T cell activation. Under normal circumstances an antigen degrades or is cleaved to form antigen fragments or peptides. Presentation of antigen fragments to T-cells is the principal function of MHC molecules, and the cells that carry out this function are called antigen-presenting cells (APC: including but not limited to dendritic cells, macrophages, and B cells).

The time course of an immune response is subdivided into the cognitive or recognition phase, during which specific lymphocytes recognize the foreign antigen; the activation phase, during which specific lymphocytes respond to the foreign antigen; and the effector phase, during which antigen-activated lymphocytes mediate the processes required to eliminate the antigen-carrying target cells. Lymphocytes are immune cells that are specialized in mediating and directing specific immune responses. T cells and B cells become morphologically distinct only after they have been stimulated by an antigen.

The capture and processing of an antigen by APCs is essential for the induction of a specific immune response. APCs capture antigens via specific receptors, such as Fc receptors or mannose receptors, or the APCs non-specifically

1 phagocytose antigen. The capture through specific receptors is more efficient;
antigens can be presented better when in complex with, for example, an antibody.
Such a complex can be formed by injecting an antibody to a circulating antigen (e.g.,
PSA or CA 125), and the immune complexes can be targeted to dendritic cells and
5 macrophages through the Fc-receptors present on these cells. However the high
number of Fc receptors on neutrophils may considerably limit this process.

Immunotherapy is based on the principle of inducing or activating the immune
system to recognize and eliminate undesirable cells, such as neoplastic cells. The key
9 elements in any immunotherapy is to induce or trigger the host immune system to
first recognize a molecule as an unwanted target, and then to induce the system to
initiate a response against that molecule. In healthy hosts, the immune system
recognizes surface features of a molecule that is not a normal constituent of the host
(i.e., is "foreign" to the host). Once the recognition function occurs, the host must
then direct a response against that particular foreign molecule.

Both the recognition and the response elements of the immune system involve
a highly complex cascade of biological reactions. In most immunologically based
disorders, at least one of the steps in the recognition phase, or at least one of the
steps in the response phase, are disrupted. Virtually any disruption in either of these
complex pathways leads to a reduced response or to the lack of any response. The
inability of the immune system to destroy a growing tumor has been attributed,
among other factors, to the presence of tumor-associated antigens (TAA) that induce
immunological tolerance and/or immunosuppression. For example, in some kinds of
cancer, the cancer itself tricks the host into accepting the foreign cancer cell as a
normal constituent, thus disrupting the recognition phase of the immune system.
25 The immunological approach to cancer therapy involves modification of the host-
tumor relationship so that the immune system is induced or amplifies its response to
the TAAs. If successful, inducing or amplifying the immune system can lead to
tumor regression, tumor rejection, and occasionally, to tumor cure.

Antigenicity and Immunogenicity

As used herein, if a binding agent can recognize an antigen, i.e., can bind to or interact with an antigen, then the antigen is said to be antigenic. If the immune system can also mount an active response against the antigen, a complex containing the antigen, a portion of the complex, or the binding agent itself, it is said to be immunogenic.

The conventional definition of an antigen is a substance (such as an antibody or an antigen) that can elicit in a vertebrate host the formation of a specific antibody or the generation of a specific population of lymphocytes reactive with the substance. As frequently occurs in science, however, it is now known that this definition, although accurate, is not complete. For example, it is now known that some disease conditions suppress or inactivate the host immune response, and the substance that would have been expected to elicit an antibody or generate specific lymphocytes, does not. Thus, not all antigens are capable of eliciting a human immune response.

Typically, the antibody's capability of binding the antigen is based on highly complementary structures. That is, the shape of the antibody must contain structures that are the complement of the structures on the antigen. The portion of the antigen to which an antibody binds is called the "antigenic determinant", or "epitope". Thus antigens are molecules that bear one or more epitopes which may be recognized by specific receptors in an immune system, a property called antigenicity.

Immunogenicity refers to the property of stimulating the immune system to generate a specific response. Thus, all immunogens are antigens, but not vice-versa. Although an immune system may recognize an antigen (e.g., binds to a T or B cell receptor), it does not respond to the antigen unless the antigen or an antigen-containing complex is also immunogenic.

An immune response to a particular antigen is greatly influenced by the structure and activity of the antigen itself, as well as myriad other factors. In some cases, the immune system is not able to generate an immune response to a particular antigen, a condition that is called tolerance.

1 In influencing whether an antigen is immunogenic or immunotolerant, an
important characteristic of the antigen is the degree of difference between the antigen
and similar molecules within the host. The most immunogenic antigens are those
that have no homologs in the host, i.e., those that are most "foreign." Other factors
5 that promote immunogenicity include higher molecular weight, greater molecular
complexity, the proper antigen dose range, the route of administration, the age of the
host, and the genetic composition of the host (including exposure to antigens during
fetal development).

9 As noted above, antigens may have one or more epitopes or binding sites that
are recognized by specific receptors of the immune system. Epitopes may be formed
by the primary structure of a molecule (called a sequential epitope), or may be
formed by portions of the molecule separate from the primary structure that
juxtapose in the secondary or tertiary structure of the molecule (called a
conformational epitope). Some epitopes, e.g., cryptic epitopes, are hidden in the three
dimensional structure of the native antigen, and become immunogenic only after a
conformational change in the antigen provides access to the epitope by the specific
receptors of the immune system. Some antigens, e.g., tumor-associated antigens such
as ovarian cancer or breast cancer antigens, have multiple antibody binding sites.
These antigens are termed "multi-epitopic" antigens.

21 An important feature and function of a comprehensive therapeutic reagent is
the ability to initiate recognition and response to an antigen, to induce a cellular and
humoral response (either or both) to the antigen, and to increase the immunogenicity
of a molecule without affecting its antigenicity.

25 Antibodies bear three major categories of antigen-specific determinants –
isotypic, allotypic, and idiotypic – each of which is defined by its location on the
antibody molecule. For the purpose of the present invention, we shall only focus on
the idiotypic category.

29 Idiotypic determinants, or idiotopes, are markers for the V region of an
antibody, a relatively large region that may include several idiotopes each capable of
interacting with a different antibody. The set of idiotopes expressed on a single

1 antibody V region constitutes the antibody idiotype. An antibody (Ab1) whose
antigen combining site (paratope) interacts with an antigenic determinant on another
antibody V region (idiotope) is called an anti-idiotypic antibody (Ab2). Thus, an Ab2
antibody includes an antigen binding site which is also an antibody binding site. A
5 portion of such anti-idiotypic antibodies (i.e., Ab2 β) will identify an epitope within
the paratope of the idiotype antibody, thus presenting an "internal" image of the
epitope identified by the idiotype antibody on the tumor associated antigen. The
phenomenon of producing an anti-idiotypic antibody having the internal image of the
9 antigen may permit the use of antibodies to replace the antigen as an immunogen.
For a graphic representation of these types of antibodies and their interaction, see
Figure 1.

For tumors that have antigens, there are at least four theories why the immune
response may fail to destroy a tumor: 1) there are no B cells or cytotoxic T
lymphocytes (CTL) capable of recognizing the tumor; 2) there are no TH cells capable
of recognizing the tumor; 3) TS cells become activated before TH cells, thus
preventing B-cell and CTL activation; and 4) the genes regulating tumor proliferation
may be present from birth, so the host does not treat the gene products as "foreign."

"Passive immunotherapy" involves the administration of antibodies to a
patient. Antibody therapy is conventionally characterized as passive since the patient
is not the source of the antibodies. However, the term passive is misleading because
the patient can produce anti-idiotypic secondary antibodies which in turn can
provoke an immune response which is cross-reactive with the original antigen.
"Active immunotherapy" is the administration of an antigen, in the form of a vaccine,
to a patient, so as to elicit a protective immune response. Genetically modified tumor
25 cell vaccines transfected with genes expressing cytokines and co-stimulatory
molecules have also been used to alleviate the inadequacy of the tumor specific
immune response.

If a specific antibody from one animal is injected as an immunogen into a
29 suitable second animal, the injected antibody will elicit an immune response (e.g.,
produce antibodies against the injected antibodies -- "anti-antibodies"). Some of these

1 anti-antibodies will be specific for the unique epitopes (idiotopes) of the variable
domain of the injected antibodies (anti-idiotypic antibodies). Others will be specific
for the epitopes of the constant domains of the injected antibodies and hence are
known as anti-isotypic antibodies.

5 The various interactions based on idiotypic determinants, called the idiotypic
network, is based on the immunogenicity of the variable regions of immunoglobulin
molecules (Ab1) which stimulate the immune system to generate anti-idiotypic
antibodies (Ab2), some of which mimic antigenic epitopes ("internal image") of the
9 original antigen. The presence of internal image antibodies (Ab2 β) in the circulation
can in turn induce the production of anti-anti-idiotypic antibodies (Ab3), some of
which include structures that react with the original antigen.

The "network" theory states that antibodies produced initially during an
immune response will carry unique new epitopes to which the organism is not
tolerant, and therefore will elicit production of secondary antibodies (Ab2) directed
against the idiotypes of the primary antibodies (Ab1). These secondary antibodies
likewise will have an idio type which will induce production of tertiary antibodies
(Ab3) and so forth.



In other words, one form of an anti-idiotypic antibody may be a surrogate
antigen.

Two therapeutic applications arose from the network theory: 1) administer
Ab1 which acts as an antigen inducing Ab2 production by the host; and 2) administer
25 Ab2 which functionally imitates the tumor antigen.

The development of the "network" theory led investigators to suggest the
direct administration of exogenously produced anti-idiotypic antibodies, that is,
antibodies raised against the idio type of an anti-tumor antibody. Such an approach is
29 disclosed in U.S. Patent 5,053,224 (Koprowski, et al.) Koprowski assumes that the

1 patient's body will produce anti-antibodies that will not only recognize these
anti-idiotypic antibodies, but also the original tumor epitope.

Conventional anti-idiotypic antibodies are made by intraspecies or interspecies
immunization with a purified antigen-specific pool of antibodies or a monoclonal
5 antibody. The resulting antiserum is then extensively absorbed against similar
molecules with the same constant region to remove antibodies with anti-C_HC_L
specificities. See, for example, Briles, et al.; "Idiotypic Antibodies," *Immunochemical
Techniques* (New York, Academic; Colowich and Kaplan, eds; 1985). The production
9 of anti-ID antibodies against self-idiotopes was one of the first key predictions of the
network theory [Rodkey, S., *J. Exp. Med* 130:712-719 (1974)].

A human anti-idiotypic monoclonal antibody (Ab2) has been shown to induce
anti-tumor cellular responses in animals and appears to prolong survival in patients
with metastatic colorectal cancer. See Durrant, L.G. et al., "Enhanced Cell-Mediated
Tumor Killing in Patients Immunized with Human Monoclonal Anti-Idiotypic
Antibody 105AD7," *Cancer Research*, 54:4837-4840 (1994). The use of anti-idiotypic
antibodies (Ab2) for immunotherapy of cancer is also reviewed by Bhattacharya-
Chatterje, et al; *Cancer Immunol. Immunother.* 38:75-82 (1994).

Idiotopes on lymphoid receptors may in some cases mimic external antigens
because of the extensive diversity of the immune system. This idea prompted many
attempts to use the internal image of a foreign antigen, mimicked by the idiotypes of
T or B receptors, to act as targets for anti-idiotypic antibodies. In this way, it has
been proposed that anti-idiotypic antibodies may induce populations of T or B cells
that can bind the extrinsic (or soluble) antigen. Such anti-idiotypic antibodies can be
used as vaccines, many of which are summarized in Greenspan, NS, and Bona, CA;
25 *The FASEB Journal*, 7:437-444 (1992).

The ability to up- or down-regulate immune responses and to control
potentially auto-reactive immunocompetent cells is vital for normal immune function
and survival. Regulatory mechanisms include the induction of clonal anergy (via
29 inappropriate antigen-presenting cells), peripheral clonal deletion/apoptosis, cytokine
(e.g. transforming growth factor-beta (TGF- β) or IL-10)-induced non-responsiveness,

1 'veto' cells, auto-reactive cytolytic T cells, and both non-specific and antigen-specific
T suppressor cells. At least in theory, each of these regulatory systems provides a
mechanistic basis for 'therapeutic intervention'.

5 In addition to cancer immunotherapy, control of abnormal acute and chronic
inflammatory response is also one of the most important challenges in medicine.
Typical examples of acute and chronic inflammation include atopy, urticaria, asthma,
autoimmune hemolytic anemia, rheumatoid arthritis, systemic lupus erythematosus,
granulomatous diseases, tuberculosis, and leprosy.

9 Like the tumor immune response described above, the aim of the
inflammatory response is the elimination of harmful agents. Further, the treatment of
autoimmune inflammatory disease is sometimes complicated by autoimmune factors
that prevent the host from eliminating the harmful agents, thereby leading to a
persistent or chronic inflammatory response or condition.

Presently, it has been determined that essential events in the development of
inflammation includes a cellular response involving neutrophils and macrophages,
specifically the rolling, activation, and adhesion of neutrophils to endothelium via
selectins-carbohydrate ligand interaction (and may include neutrophil extravasation).

Therapeutic compositions for the treatment of inflammation have included
agents that bind to one or more of the mediators of inflammation. For example,
antibodies specific for selectin carbohydrate ligands, and inhibiting selectin-
carbohydrate ligand binding, may be important anti-inflammatory targets for the
development of therapeutic compositions for the treatment of inflammation.

In addition to the above, there are other cases where an anti-idiotypic mode of
induction of a response may be useful. If a given epitope of a protein is
25 discontinuous and results from three-dimensional folding, an anti-Id can be produced
that would mimic that structure. Further, in immunizing against latent and/or
immunosuppressive viruses, there is the possibility of well known deleterious effects
not solvable by the use of attenuated viruses (e.g., mumps, measles, rubella, and
29 HIV). The use of anti-ID induction of protective immunity may avoid these
deleterious effects.

Summary of the Invention

The present invention is a method and composition for generating both a humoral and/or a cellular immune response by administering a binding agent that specifically binds to a pre-selected soluble antigen. In accordance with the invention, the binding agent-soluble antigen complex alters the immunogenic condition of the host by generating new immunogens that are recognizable by the immune system. This leads to a humoral and/or a cellular response. In one embodiment of the invention, the immune response comprises an anti-tumor response and/or cell killing.

The present invention is a comprehensive method for the treatment of certain diseases and conditions that includes, but is not limited to, targeting a pre-determined antigen, preferably a multi-epitopic antigen and/or preferably soluble; administering a binding agent, preferably a monoclonal antibody, and inducing a comprehensive immune response against the disease or condition that generated the target antigen. In a preferred embodiment of the invention, the binding agent or the binding agent/antigen complex induces the production of a humoral response, as evidenced in part by the production of anti-antigen (e.g., anti-tumor or anti-inflammation) antibodies, Ab3 and/or Ab1c; and/or induces the production of a cellular response, as evidenced in part by the production of T-cells that are specific for the binding agent, the binding agent/antigen complex, and/or the antigen.

The present invention also includes methods and compositions for altering the immunogenic state of the host organism. In altering the immunogenic state, the compositions and methods of the present invention increase, decrease, or maintain the host's immunogenic state. An example of deriving a therapeutic benefit by increasing the immunogenicity includes but is not limited to treatments for cancer or some infectious diseases. An example of decreasing the immunogenicity includes but is not limited to treatments for rheumatoid arthritis. An example of maintaining immunogenicity includes but is not limited to supplemental treatments for patients that have become tolerant to antigens after an initial response. In a most preferred embodiment of the invention, the methods and compositions do not decrease the antigenicity of the active component in the therapeutic composition.

1 The present invention also includes methods and compositions for increasing
the over-all host response to a disease or condition. These methods and compositions
produce a therapeutic benefit for the recipient.

5 The present invention also is a therapeutic composition comprising an active
agent, or binding agent, that specifically binds to a pre-determined soluble antigen,
wherein the binding agent, upon binding to the antigen, forms a complex that is both
antigenic and immunogenic.

9 The compositions and methods of the present invention may also include one
or more steps or substances that increase the over-all immunogenicity.

 The therapeutic compositions and methods of the present invention are
suitable for the treatment of any disease or cancer that produces a soluble antigen,
preferably a multi-epitopic antigen.

 The present invention also includes a method for designing new therapeutic
agents comprising selecting a soluble antigen, preferably an antigen that has been
determined to be multi-epitopic; and selecting a binding agent that specifically binds
to said antigen to form a complex. In accordance with the invention, the binding
agent, the binding agent/antigen complex, and/or the antigen lead to the production
of a humoral and/or cellular response *in vivo*. In a preferred embodiment of the
invention, the method for designing a new therapeutic agent results in a binding
agent or the binding agent/antigen complex that induces the production of a
humoral response, as evidenced in part by the production of anti-tumor or anti-
inflammation antibodies, Ab3 and/or Ab1c; and/or induces the production of a
cellular response, as evidenced in part by the production of T-cells that are specific
for the binding agent, the binding agent/antigen complex, and/or the antigen.

25 Although several investigators have shown that antigen-specific antibodies can
enhance the immune response to those antigens presented in a complex form, the
present invention is the first to demonstrate that the injection of an antibody against a
single epitope can induce a multi-epitopic immune response in cancer patients,
29 provided that the patients' sera contained the respective antigen. The present
invention also demonstrates that this antibody injection can change the patient's

1 immune response in such a way that the self-protein CA125 can now be recognized
by the immune system.

Stimulation of T cells reactive with subdominant or cryptic epitopes of self-
proteins has been suggested as an important factor in inducing immunity to a pre-
5 determined antigen, e.g., an antigen involved in a disease or condition such as
cancer or auto-immunity. Antibody-enhanced or -altered presentation of an antigen,
such as CA125, in an antibody complex, e.g., bound to MAb-B43.13, by B cells
(antibody-specific), or macrophages or dendritic cells (both Fc receptor mediated),
9 may result in presentation of different peptides to the immune system than those
obtained by presentation of the antigen alone. This can lead to sufficient presence of
antigen-specific peptides from subdominant or cryptic epitopes which may in turn
stimulate low-affinity T cells that escaped clonal deletion in the thymus or re-
stimulate T cells which were suppressed. The immune response induced by
exogenous administration of an antibody to a circulating self-antigen can therefore be
compared to that observed in auto-immune diseases. This may also explain why
presence of immune complexes of antigen with autologous human antibodies is often
not correlated with improved survival. Human B cells recognize preferably immune-
dominant epitopes of the antigen, leading to presentation of epitopes against which T
cells were formed during fetal development. Murine antibodies on the other hand,
recognize immune-dominant epitopes in mice which are not necessarily equivalent to
the human immune-dominant epitopes.

The capture and processing of an antigen, e.g., PSA, by B-cells may also occur
through the interaction of the membrane bound Ab2 with the anti-antigen/antigen
(e.g., anti-PSA/PSA) complexes and in a similar manner through the interaction of
25 membrane bound Ab3 with the antigen (complexed or not with the anti-PSA
antibody). Although applicants do not wish to be bound by any particular theory
of operability, it is believed that the observed immunological response achieved by
the present invention is attributable to an interaction between a newly formed
29 antigen and the human patient's immune system. As noted above, a portion of the
immune response includes inducing the production of anti-(anti-idiotypic) antibodies

1 by the patient. Within this set of anti-(anti-idiotypic) antibodies are those that are
directly complimentary to the paratope of an anti-idiotypic antibody. It is further
believed that the paratope of the anti-idiotypic antibody presents an "internal" image
of the tumor cell epitope identified (i.e., selectively bound) by the idiotype antibody
5 and , therefore, the anti-(anti-idiotypic) antibodies will also bind the tumor antigen. In
effect, the present method induces a immunological response to the first antigen, e.g.,
a tumor antigen, by presenting a second antigen (the paratope of the anti-idiotypic
antibody, which shares homologies with the tumor antigen) to a portion of the
9 patient's resulting antibodies.

The present invention concerns altering immunogenicity in a manner that
produces a beneficial or therapeutically desirable effect. As used herein and as
described in more detail below, a beneficial or desirable immune response is one that
produces a therapeutically desirable result. A beneficial therapeutic response will
typically include activation of the immune system and/or one or more of its
components, induction of the immune system and/or one or more of its components,
and/or a T cell immune response, and/or a humoral immune response, and/or
17 reduction in tumor burden, and/or an increase in survival time, and/or the like. For
example, for a cancer such as ovarian cancer, a beneficial or desirable immune
response includes the production of an antibody that immunoreacts with a previously
non-immunoreactive ovarian cancer antigen. In this example, the immune response
to an antigen is increased. In another example, for a condition such as inflammation,
a beneficial or desirable immune response includes the production of an antibody
that immunoreacts with a previously immunoreactive antigen so that it becomes non-
immunoreactive. In this example, the immune response is decreased. In
25 transplantation, the immune system attacks MHC-disparate donor tissue leading to
graft rejection, in autoimmune disease it attacks normal tissues, and in allergy the
immune system is hyper-responsive to otherwise harmless environmental antigens.
It is now recognized that immunosuppressive therapy may be appropriate for
29 treating each of these disorders.

Description of the Figures

Figure 1 is a graphic representation of the different types of antibodies and their structural relationship to each other and to an antigen.

Figure 2 shows the production of Ab2 in response to the administration of a composition of the invention.

Figure 3 shows the production of B cells in response to the administration of a composition of the invention. Legend: open bars, 0.1 μ g or kU per mL; hatched bars, 1 μ g or kU per mL; closed bars, 10 μ g or kU per mL.

Figure 4 shows that a binding agent/antigen complex stimulates an immune response. Legend: open bars, 0.1 μ g or kU per mL; hatched bars, 1 μ g or kU per mL; closed bars, 10 μ g or kU per mL.

Figure 5 shows the ability of a composition of the invention to increase the immunogenicity of its target antigen. Legend: •, MAb 43.13; ■, MAb 43.13 + CA 125; ▲, CA 125.

Figure 6 shows the characterization of anti-CA 125 antibodies from patients injected with MAb B43.13. Anti-CA 125 positive samples were tested for inhibition of their binding to CA 125 (solid phase) by CA 125, MAb-B43.13 scFv, MAb-B27.1 F(ab'), or MAb M11 F(ab'). Single chain MAb-B43.13, F(ab') MAb-B27.1, and F(ab') M11 were used in the inhibition studies to avoid non-specific inhibition of the Fc portion of the antibody and cross-reactivity due to HAMA. To be considered to be significant, inhibition had to be at least 15%.

Figure 7 shows a humoral response generated by an anti-MCV-1 antibody.

Figure 8 shows a humoral response generated by a composition of the invention directed against breast cancer.

Figure 9 shows that Alt-3 and Alt-2 binding agents are effective in complement-mediated cytotoxicity.

Figure 10 shows the reduction in gastro-intestinal tumor volume after administration of a anti-CA19.9 antibody.

Figure 11 shows the results and characteristics of an anti-inflammatory anti-CA19 antibody.

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1 the antigen (Ab1c, which is used interchangeably with Ab3'), cytotoxic lymphocytes, such as killer T cells or natural killer (NK) cells, and/or T cell proliferation.

5 A composition and method of the present invention includes administering an effective amount of a binding agent that specifically binds to a pre-determined antigen, wherein the antigen is preferably present *in vivo* in a high amount, allowing the binding agent to bind to the antigen, and inducing the production of a beneficial immune response against the antigen.

9 The present invention also includes compositions and methods that result in the induction of a beneficial immune response, particularly where one skilled in the art would not expect to find an antigen-specific immune response, e.g., tumor-associated antigens ("self") antigens.

13 An additional composition of the present invention may also include a modified antigen, wherein a soluble, preferably multi-epitopic, antigen is modified by binding to a binding agent. An additional method of the present invention may include producing the modified antigen, and/or using the modified antigen to achieve a therapeutic effect, e.g., producing, inducing, or inhibiting an immune response against the antigen.

17 In one embodiment of the invention, the methods and compositions include all binding agents as defined herein, exclusive of B43.13 antibodies. For example, a method and composition of the invention may include a composition comprising a binding agent that is free of, or substantially free of, B43.13 antibodies.

21 The invention further includes methods and compositions for treating ovarian cancer comprising a binding agent that specifically binds to an ovarian cancer antigen, such as CA 125, wherein said binding agent is exclusive of B43.13 antibodies, wherein the complex between the binding agent and the antigen is immunogenic.

25 In certain embodiments the invention provides a method for inducing a host immune response against a multi-epitopic *in vivo* antigen, such as a tumor associated antigen or a non-tumor associated antigen, present in the host's serum, which antigen
29 preferably does not elicit an effective host immune response, the method comprising

1 contacting the antigen with a composition comprising a binding agent that
specifically binds to a first epitope on the antigen and allowing the binding agent to
form a binding agent/antigen pair wherein a host immune response is elicited
against a second epitope on the antigen. The present invention involves contacting
5 an antigen, preferably a soluble antigen, with a composition of the invention, and
reacting a binding agent in the composition with the antigen. In accordance with the
invention, binding the antigen with the binding agent generates host recognition of
the antigen. In turn, generating host recognition leads to initiating an immune
9 response against the antigen.

In certain embodiments the invention provides a method for inducing an
immune response against an antigen that does not elicit an effective host immune
response, the method comprising administering to the host a low dose or a small
amount of a binding agent that binds an epitope of a soluble form of the antigen. In
certain embodiments the invention provides a method for inducing an immune
response against an antigen that does not elicit an effective host immune response,
the method comprising administering to the host a binding agent that binds an
epitope of a soluble form of the antigen using a low dose of binding agent, preferably
a dose that does not produce ADCC and/or induce antibody-mediated toxicity. In
some embodiments of the invention, low dose of binding agent comprises from about
0.1 μ g to about 2 mg per kg of body weight of the host. In some embodiments of the
invention, the antigen is a cellular antigen. ADCC is assessed by incubating ⁵¹Cr-
labeled tumor cells with a binding agent according to the invention and adding fresh
human PBMCs, followed by incubation for four hours and measurement of specific
lysis. ADCC is deemed to be absent if specific lysis is less than 15%. As used herein,
25 antibody-mediated toxicity refers to clinical toxicity, specific indicators of which
include, but are not limited to, abnormal serum chemistries, impaired renal function,
and signs and symptoms of serum sickness or anaphylaxis.

In certain embodiments, the invention provides a method comprising
29 intravenously administering to the host a binding agent that binds an epitope of a
soluble form of a cellular antigen.

1 In certain embodiments the host immune response comprises a cellular and
humoral immune response. In certain embodiments, the host immune response
comprises a cellular response. In certain embodiments, the host immune response
comprises a humoral response. In certain embodiments, the antigen is a soluble
5 antigen. In certain embodiments the binding agent is an antibody. In certain
embodiments, the antibody is a murine monoclonal antibody. In certain
embodiments the antibody does not induce antibody-mediated toxicity, e.g., isotypic
induced HAMA toxicity, in the host. In certain embodiments the antigen is
9 associated with a human disease or pathological condition. In certain embodiments
the disease or pathological condition is cancer. In certain embodiments the binding
agent is photoactivated. In certain embodiments the humoral response comprises
anti-idiotypic antibodies. In certain embodiments, the amount of binding agent is at
least 0.1 μg and preferably up to 2 mg, more preferably between 1 μg and 200 μg per
kg of body weight of the host.

13 In certain embodiments, the invention provides a therapeutic composition
comprising a binding agent specific for a first epitope on a multi-epitopic antigen,
17 which may be a tumor associated antigen or a non-tumor associated antigen, present
in the host's serum, which antigen preferably does not elicit an effective host
immune response, wherein the binding agent specifically binds to a first epitope on
the antigen and forms a binding agent/antigen pair wherein a host immune response
21 is elicited against a second epitope on the antigen. In preferred embodiments of the
invention, the binding agent is an antibody, preferably an activated antibody, and
most preferably, a photoactivated antibody.

25 In certain embodiments the invention provides a therapeutic composition
comprising a low dose of a binding agent that binds an antigen, preferably a soluble
or cellular antigen, which does not elicit an effective host immune response, wherein
the binding agent specifically binds to the antigen and induces an immune response
against the antigen. Preferably, the low dose of a binding agent is from about 0.1 μg to
29 about 2 mg per kg of body weight of the host.

1 In certain embodiments the invention provides a therapeutic composition for
intravenous administration comprising a binding agent that binds a soluble form of a
cellular antigen which does not elicit an effective host immune response, wherein the
binding agent specifically binds to the antigen and induces an immune response
5 against the antigen. In a preferred embodiment of the invention, compositions
administered intravenously preferably do not include adjuvant. In certain
embodiments the invention provides a therapeutic composition for subcutaneous
administration comprising a binding agent that binds an epitope of a soluble form of
9 a cellular antigen which does not elicit a host immune response, wherein the binding
agent specifically binds to the epitope and induces an immune response against the
cell surface form of the antigen. As used herein, a "soluble form of a cellular antigen"
refers to a circulating form of an antigen that is also expressed on a cell surface. In a
preferred embodiment of the invention, compositions administered subcutaneously
preferably include adjuvant.

Those skilled in the art will recognize that these embodiments may be used
alone, or in any combination.

In accordance with the present invention, the inventors believe the interaction
between the antigen and the binding agent may effectively present a previously
unexposed or suppressed epitope to the patient's immune system to generate: 1) a
humoral response resulting in human anti-tumor antibodies that may or may not be
inhibitable by the injected antibody, but are definitely inhibitable by an antibody that
binds to an epitope different from the epitope reactive with the injected binding
agent; and 2) a cell-mediated response resulting in the production of antigen-specific
T-cells.

25 One skilled in the art will recognize that an aspect of any antibody-based
immunotherapy is the interaction between the antigen and the antibody. Also, the
success, effectiveness, and usefulness of that binding event typically involves a wide
variety of sometimes interwoven factors. In general, these factors include but are not
29 limited to the binding capacity of the binding agent, immunogenicity of the binding
agent, accessibility of the antigen, accessibility of the antigen's epitope, the degree of

1 complementarity between the paratope of the binding agent and the epitope of the
antigen, the effect of the binding event on the complex, the complex's capability of
inducing an immune response, and the extent to which the immune response is
activated. It is intended that these factors contribute to the determination of an
5 appropriate or desirable binding agent and/or pre-determined antigen, and to the
nature and effectiveness of the resulting immune response.

The interplay of these various considerations, as taught by the present
invention, may lead one to effective therapeutic remedies. In the case of B43.13 and
9 the treatment of ovarian cancer, a specific example used to prove the general point
without thereby limiting the invention, B43.13 is a murine antibody, so its
heterogeneity in a human system contributes to its immunogenicity. Further, CA 125,
the target antigen, is a soluble, tumor associated antigen, and thereby accessible to a
binding agent. The binding event between B43.13 and CA 125 is of such a nature
that one or more epitopes on the complex become available to components of the
immune system, thus inducing an immune response where previously there was
none (or so little that no therapeutic benefit was derived). Further, the binding event
created access to an epitope on the complex that was suitable for inducing both
humoral and cellular immune responses, thus inducing a comprehensive immune
response that is itself a beneficial immune response. As pertains B43.13, all of these
individual elements contributed to the recognition of the use of B43.13 to induce an
immune response cascade that is effective in the treatment of ovarian cancer.

As noted above, the inventors believe that an important aspect of inducing or
mediating a cellular and humoral response lies in part in increasing the
immunogenicity of the binding agent-antigen complex while maintaining its
25 antigenicity. As described in more detail below and in the Examples, increasing
immunogenicity while maintaining antigenicity may be affected by one or more of
the following:

- 29 1. Administering a dose of binding agent that is low in
comparison to the dose for other therapeutic compositions;

2. Forming a binding agent-antigen complex *in vivo* or *ex vivo*;
3. Photoactivating the binding agent prior to administration
4. Administering the binding agent in a microsphere, liposome, nanosphere, or micelle;
5. Conjugating the binding agent to a photodynamic agent, such as hypocrellin B; and
6. Conjugating the binding agent to immune effectors.

In a preferred embodiment of the invention, a composition comprising a pre-determined antibody that specifically binds to a pre-determined tumor associated antigen is used to bind a soluble antigen produced by the tumor. Once the soluble antigen is bound, the immune system recognizes the antigen as "foreign," and mounts an immune response against the antigen or against the binding agent bound to the antigen. Antigens that can be made immunogenic are potentially useful to induce or activate an immune response, leading to therapeutic and possibly prophylactic benefits.

Any composition that includes a binding agent according to the invention may be used to initiate an *in vivo* immune response. The composition may include one or more adjuvants, one or more carriers, one or more excipients, one or more stabilizers, one or more imaging reagents, one or more effectors; one or more photodynamic agents; and/or physiologically acceptable saline. Generally, adjuvants are substances mixed with an immunogen in order to elicit a more marked immune response. Control vaccinations without the adjuvant resulted in humoral immune responses. In a preferred embodiment of the invention, the composition comprising a binding agent does not include adjuvant.

In a preferred embodiment of the invention, a suitable composition includes a binding agent that binds to a soluble antigen to form a complex that is itself antigenic and immunogenic. In a most preferred embodiment of the invention, the complex is an antigen that induces a beneficial or desirable therapeutic effect.

1 The composition may also include pharmaceutically acceptable carriers.
Pharmaceutically accepted carriers include but are not limited to saline, sterile water,
phosphate buffered saline, and the like. Other buffering agents, dispersing agents,
and inert non-toxic substances suitable for delivery to a patient may be included in
5 the compositions of the present invention. The compositions may be solutions
suitable for administration, and are typically sterile and free of undesirable
particulate matter. The compositions may be sterilized by conventional sterilization
techniques.

9 In accordance with the teachings of the present invention, the methods and
compositions produce both a humoral and cellular response. Those skilled in the art
will readily recognize that determining that a humoral and/or cellular response has
been generated is easily shown by testing for the structures associated with each
response. For example, evidence of the production of a humoral response includes
but is not limited to the production of Ab2 and Ab3. Likewise, evidence of the
production of a cellular response includes but is not limited to the production of T2
and/or T3 cells.

BINDING AGENTS

13 The binding agents of the present invention bind an antigen of interest, and
the resulting immunogenic pair or complex may be used to prime or initiate an
immune response, typically to another epitope on the complex or a portion of the
complex. The epitope, which previously did not elicit an effective immune response,
upon being recognized by agents of the immune system, initiates the immune system
cascade that results in a beneficial immune response, preferably an effective immune
25 response as used herein, an effective host immune response means amelioration or
elimination of the disease or condition that produces the antigen.

29 A binding agent (BA), as used herein, refers to one member of a binding pair,
including an immunologic pair, e.g., a binding moiety that is capable of binding to an
antigen, preferably a single epitope expressed on the antigen, such as a pre-
determined tumor antigen. In some embodiments of the invention, the binding

1 agent, when bound to the antigen, forms an immunogenic complex. Exemplary
binding agents include, but are not limited to: monoclonal antibodies ("MAb"),
preferably IgG1 antibodies; chimeric monoclonal antibodies ("C-MAb"); humanized
antibodies; genetically engineered monoclonal antibodies ("G-MAb"); fragments of
5 monoclonal antibodies (including but not limited to "F(Ab)₂", "F(Ab)" and "Dab");
single chains representing the reactive portion of monoclonal antibodies ("SC-MAb");
antigen-binding peptides; tumor-binding peptides; a protein, including receptor
proteins; peptide; polypeptide; glycoprotein; lipoprotein, or the like, e.g., growth
9 factors; lymphokines and cytokines; enzymes, immune modulators; hormones, for
example, somatostatin; any of the above joined to a molecule that mediates an
effector function; and mimics or fragments of any of the above. The binding agent
may be labeled or unlabeled.

A binding agent according to the invention is preferably a monoclonal or
polyclonal antibody. The antibody includes, but is not limited to native or naked
antibodies; and modified antibodies, such as activated antibodies, e.g., chemically
activated or photoactivated antibodies. As used herein, native refers to a natural or
normal antibody; naked refers to removing a non-native moiety, e.g., removing the
label from a labeled antibody. In a most preferred embodiment of the invention, the
binding agent is an Ab1 antibody that induces the production of one or more
molecules that comprise an immune response, including but not limited to one or
more of the following: molecules associated with a cellular response (cytokines,
chemokines, cytotoxic T lymphocytes (CTL), and natural killer cells (NK)), and/or
molecules associated with a humoral response [Ab3, Ab1c (sometimes referred to as
Ab3')].

25 Those skilled in the art are enabled to make a variety of antibody derivatives.
For example, Jones *et al.*, Nature 321: 522-525 (1986) discloses replacing the CDRs of
human antibody with those from a mouse antibody. Marx, Science 229: 455-456
(1985) discusses chimeric antibodies having mouse variable regions and human
29 constant regions. Rodwell, Nature 342: 99-100 (1989) discusses lower molecular
weight recognition elements derived from antibody CDR information. Clackson, Br.J.

1 Rheumatol. 3052: 36-39 (1991) discusses genetically engineered monoclonal antibodies,
including Fv fragment derivatives, single chain antibodies, fusion proteins chimeric
antibodies and humanized rodent antibodies. Reichman *et al.*, Nature 332: 323-327
5 (1988) discloses a human antibody on which rat hypervariable regions have been
grafted. Verhoeyen, *et al.*, Science 239: 1534-1536 (1988) teaches grafting of a mouse
antigen binding site onto a human antibody. Biospecific antibodies are also known in
the art.

Methods for producing and obtaining an antibody are well known by those
9 skilled in the art. An exemplary method includes immunizing any animal capable of
mounting a usable immune response to the antigen, such as a mouse, rat, goat sheep,
rabbit or other suitable experimental animal. In the case of a monoclonal antibody,
antibody producing cells of the immunized animal may be fused with "immortal"
or "immortalized" human or animal cells to obtain a hybridoma which produces the
antibody. If desired, the genes encoding one or more of the immunoglobulin chains
may be cloned so that the antibody may be produced in different host cells, and if
desired, the genes may be mutated so as to alter the sequence and hence the
immunological characteristics of the antibody produced. Fragments of binding agents,
may be obtained by conventional techniques, such as by proteolytic digestion of the
binding agent using pepsin, papain, or the like; or by recombinant DNA techniques
in which DNA encoding the desired fragment is cloned and expressed in a variety of
hosts. Irradiating any of the foregoing entities, e.g., by ultraviolet light, will enhance
the immune response to the antigen. In a preferred embodiment of the invention,
effector functions that mediate CDC or ADCC are not required. Various binding
agents, antibodies, antigens, and methods for preparing, isolating, and using the
25 binding agents are described in U.S. Patent 4,471,057 (Koprowski), U.S. Patent
5,075,218 (Jette, et al.), U.S. Patent 5,506,343 (Kufe), and U.S. Patent 5,683,674 (Taylor-
Papadimitriou, et al), all incorporated herein by reference. Furthermore, many of
these antibodies are commercially available from Centocor, Abbott Laboratories,
29 Commissariat a L'Energie Atomique, Hoffman-LaRoche, Inc., Sorin Biomedica, and
FujiRebio.

1 The preferred binding agents of the present invention, murine monoclonal
antibodies, may be produced according to conventional techniques well known to
those skilled in the art. Hybridoma production in rodents, particularly in mice, is a
very well established procedure and is preferred. Stable murine hybridomas provide
5 an unlimited source of antibody of select or pre-determined characteristics. Typically,
a monoclonal antibody can be prepared using any technique which provides for the
production of antibody molecules by continuous cell lines in culture. These include
but are not limited to the hybridoma technique originally described by Kohler and
9 Milstein [*Nature*, 256:495-497 (1975)]; the human B-cell hybridoma technique [Kozbor,
et al., *Immunology Today*, 4:72 (1983)]; and the EBV transformation technique [Cole,
et al., *Monoclonal Antibodies and Cancer Therapy*, Alan R. Liss, Inc., pp. 77-96
(1985)].

13 Briefly, a monoclonal antibody of the invention may be produced by
immunizing an animal, typically a mouse, with an immunogen, e.g., an antigen such
as CA 125. The invention includes but is not limited to the use of a peptide segment
that includes a specific epitope or pre-determined amino acid sequence. These
17 peptides can be synthesized and optionally conjugated to a carrier protein, such as
keyhole limpet hemocyanin (KLH), and used as an immunogen.

21 The procedure is then followed by obtaining immunized lymphoid cells (e.g.,
splenic lymphocytes) from the immunized animals, fusing the lymphoid cells with
an immortalized cell (e.g., a myeloma or a heteromyeloma) to produce hybrid cells
that can be propagated in culture indefinitely, and then screening the hybrid cells to
24 identify those that produce monoclonal antibodies that react with the target epitope.

25 The resulting hybridoma can be selected by any of numerous assays, e.g., for
binding to Ab2, or for inhibiting Ab1 binding to tumor cells. For example, the
binding site epitope or peptide sequences containing the epitope can be synthesized
and/or immobilized on polyethylene pins or another support. The appropriate
monoclonal antibody can then be determined by its capacity to bind the immobilized
29 peptide, as detected by ELISA using a labeled antibody (labeled with, e.g.,
peroxidase).

1 If desired, murine or other animal antibodies may be humanized following any
of a number of procedures well known in the art. For example, Reichmann et al
[Nature, 322:323-327 (1988)] used recombinant DNA methodology to replace the six
hypervariable regions from the human antibody heavy and light chain variable
5 domains with the hypervariable regions from the rodent antibodies. The reshaped
human antibodies have the affinity of the original antibodies due to the presence of
the original hypervariable regions, but would have all other characteristics of a
human antibody.

9 One of the most promising approaches to tumor immunotherapy is to use
antibody fragments or antibody fragments with effector domains to target and kill
tumor cells. Single-chain Fv (scFv) has been genetically engineered as a recombinant
fusion protein that is composed of a heavy chain (Vh) and a light-chain (Vl) variable
domain connected by an artificial linker and an effector domain.

13 In some preferred embodiments, the binding agents according to the invention
are activated, preferably by chemical or photodynamic approaches. Preferred
chemical approaches include organic reducing agents, such as formamidine sulfonic
acid, inorganic reducing agents, mercurous ion, stannous ion, cyanide ion, sodium
17 cyanoborohydride and sodium borohydride, thiol exchange reagents, such as
dithiothreitol, mercaptoethanol and mercaptoethanolamine, and protein reducing
agents, such as thioredoxin. Use of these reagents results in reduction of some
disulfides within the binding agent to produce a binding agent having some
21 sulfhydryl groups. The presence of such groups can change the tertiary structure of
the binding agent. Such structural change can modulate the immunoreactivity of the
binding agent. Such modulation may lead to an improved anti-idiotypic response
25 and/or cellular response in an individual to whom the binding agent is administered.

29 In some preferred embodiments, the binding agents according to the invention
may optionally be coupled to photodynamic agents. Preferably, such coupling is by
covalent linkage or by liposomal association. Liposomal association is preferably
achieved by mixing the photodynamic agent with a binding agent in the presence of
a liposome -forming reagent. In certain preferred embodiments, the binding agent

1 according to the invention is covalently linked to the liposome -forming reagent.
Preferred photodynamic agents include hypocrellins, such as hypocrellin B, more
preferably, aminated hypocrellins and hypocrellin derivatives.

5 In an embodiment of the invention, a suitable composition for the treatment of
an ovarian tumor associated antigen contains a binding agent that binds the CA 125
antigen. Exemplary antibodies that bind to CA 125 include, but are not limited to
B43.13. The present invention also includes the use of any binding agent other than
B43.13 that specifically binds to CA 125 and that results in a beneficial immune
9 response, e.g., M11. These and other exemplary antibodies are disclosed in Nustad,
et al, *Tumor Biology*, 17:196-219 (1996) and Nap, et al, *Tumor Biology*, 17:325-331 (1996).

13 In another embodiment of the invention, a suitable composition for the
treatment of gastrointestinal cancer contains a binding agent that binds the CA 19.9
antigen. Exemplary antibodies that bind to CA 19.9 include, but are not limited to
Alt-3, W25 (CIS Bio International), A3 (Shemyakin Inst. Biorg. Chem.), and NS116-
NS-19.9 (Centocor), among others. These and other exemplary antibodies are
disclosed in *Tumor Biology*, 19:390-420 (1998).

17 In yet another embodiment of the invention, a suitable composition for the
treatment of breast cancer contains a binding agent that binds the CA 15.3 antigen.
Exemplary antibodies that bind to CA 15.3 include, but are not limited to SM-3, DF-3,
DF3-P, Ma 552, and BC4E549. These and other exemplary antibodies are disclosed in
21 *Tumor Biology*, 19:21-29 (1998).

25 In yet another embodiment of the invention, a suitable composition for the
treatment of prostate cancer contains a binding agent that binds the prostate specific
antigen (PSA). An exemplary antibody that binds to PSA includes, but is not limited
to AR47.47.

29 In yet another embodiment of the invention, a suitable composition for the
treatment of inflammation includes a binding agent that binds CA 19.9 antigen.
Exemplary antibodies that bind to CA 19.9 and reduce inflammation include but are
not limited to Alt-3 and Alt-4 antibodies.

1 SOLUBLE ANTIGEN

A pre-determined antigen may be any human or mammalian antigen of clinical significance. In accordance with the present invention, the pre-determined or target antigen must be capable of binding a binding agent. Capable of binding
5 includes, but is not limited to one or more of the following: the antigen may be soluble, circulating, present, detectable, and/or include a binding site accessible to an administered binding agent.

In a preferred embodiment of the invention, the antigen is a tumor-associated
9 antigen (TAA). In the case of TAA, the cancer may include, but is not limited to lung, colon, rectum, breast, ovary, prostate gland, head, neck, bone, immune system, or any other anatomical location. Illustrative tumors and tumor markers are listed in U.S. Patent 5,075,218.

The methods of the present invention may involve any cancer that produces a soluble multi-epitopic TAA. As used herein soluble is used to describe any antigen that is detectable in a body fluid, i.e., blood, serum, ascites, saliva, or the like. In accordance with the present invention, the preferred tumors are those that: shed soluble tumor antigens, e.g., tumor antigens shed into the bloodstream, as opposed to a surface antigen or an intracellular antigen; exhibit a multi-epitopic tumor associated antigen, and can be found at a concentration in the patient's body fluid more than is normally present in healthy controls and such a high level signifies presence of the disease, yet has not initiated a significant immune response. In a preferred
embodiment, the pre-determined antigen is an antigen that does not elicit an effective host immune response, e.g., is not effective in reducing tumor burden and/or does not induce a therapeutic benefit (even if a small immune response is generated). As
25 is well known by one skilled in the art, one method of determining whether the concentration of the TAA is greater than in healthy individuals is by comparing the patient's concentration to that of a healthy control. If the concentration of the TAA is higher than the healthy control, then the patient's concentration is predictive of
29 presence or recurrence of the disease.

1 The invention also involves the production of a modified antigen, typically by
producing the modified antigen *in vivo*. As used herein, modified antigen refers to a
first antigen, typically invisible to the immune system, that binds to a binding agent,
and the binding agent-antigen is itself an antigen (the "second" antigen) that is
5 immunoreactive with one or more molecules of the immune system.

As used herein, "disease" refers to the management, diagnosis, and/or
palliation of any mammalian (including human) disease, disorder, malady, or
9 condition. "Disease" includes but is not limited to cancer and its metastases, such as
skin cancer; growths or tumors, and their metastases; tumors and tumor cells, such as
sarcomas and carcinomas, including solid tumors, blood-borne tumors, and tumors
found in nasal passages, the bladder, the esophagus, or lung, including the bronchi ;
viruses, including retroviruses and HIV; infectious diseases, such as hepatitis,
including chronic hepatitis such as hepatitis B; bacterial diseases; fungal diseases; and
dermatological conditions or disorders, such as lesions of the vulva, keloid, vitiligo,
psoriasis, benign tumors, endometriosis, Barrett's esophagus, *Tinea capitis*, and lichen
amyloidosis; and autoimmune disorders, such as rheumatoid arthritis. Exemplary
soluble multi-epitopic antigens are described above, and include but are not limited
to CA 125, CA 19.9, CA 15.3, polymorphic epithelial mucin (PEM), CEA, and prostate
specific antigen.

It should be noted that many of these diseases and/or disorders are
characterized in part by including symptoms or biological processes involved with
inflammation. Many types of immune-mediated inflammation, including chronic and
acute inflammation, and many types of arthritis, including rheumatoid arthritis, and
25 many types of cancer all express or involve the same or similar carbohydrate ligands.
Exemplary ligands include, but are not limited to SLe^a and SLe^x. An embodiment of
the invention includes compositions that include in part one or more binding agents
that bind to a carbohydrate ligand. These compositions are effective against any
29 disease or condition that involves the carbohydrate ligand as part of its metabolic
pathway, including, but not limited to rheumatoid arthritis, collagen-induced

1 arthritis, adjuvant arthritis, and pristane-induced arthritis. For purposes of this
aspect of the invention only, an "effective host immune response" means eliminating
harmful factors, thereby eliminating a persistent or chronic inflammatory response or
condition.

5 A high level of antigen, as used herein, is a variable term dependent in part on
the type of the antigen, and/or the type of disease or condition, and/or the stage of
the disease or condition. For example, one skilled in the art will recognize that a
high level may mean that a majority of cancer-positive patients, e.g., above 50% or
9 above about 80%, have a certain amount of circulating antigen. For example, the
present understanding of the course of ovarian cancer suggests that 80% or higher of
the patients having greater than 35 U/ml of CA 125 antigen in their bloodstream
have a statistically significant higher risk of developing ovarian cancer. A high level
also may be defined in terms of the amount sufficient to completely or substantially
completely bind all of a pre-determined dose of binding agent. A high level may
also be defined as a threshold quantity of circulating antigen that those skilled in the
art recognize as a high level. A high level may also include that amount that is
predictive of disease. A high level may also include an amount or concentration of
antigen higher than what is normal for that patient or for that disease or condition.

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29 A method of an embodiment of the invention includes determining the
amount of pre-determined antigen in the patient, e.g., circulating in the patient, and if
the amount of antigen is a high level, then administering a composition comprising a
binding agent according to the invention. A more preferred method of the invention
includes determining the amount of circulating pre-determined antigen in the patient
and, if the amount is greater than an amount predictive of the disease, more
preferably three times greater, then administering a composition comprising a
binding agent according to the invention. For example, a method of the invention
includes determining the amount of circulating CA 125, and if the amount is greater
than about 35 U/ml, and more preferably greater than about 105 U/ml, then
administering a composition comprising a binding agent according to the invention,

1 e.g., comprising B43.13. The administered composition may include a low dose of binding agent.

As noted in the background section, the potential effect of injecting a binding agent such as an antibody can be extremely complex and may typically involve
5 distinct mechanisms of action. As used in herein, Ab3 and Ab1c represent two such distinct mechanisms that individually and/or collectively produce a beneficial effect. In the Ab3 pathway, an Ab1 antibody that is capable of binding to a pre-determined antigen may induce the production of an anti-idiotypic antibody (Ab2 β) that mimics
9 an epitope of the antigen. The anti-idiotypic antibody in turn may induce the production of anti-anti-idiotypic antibodies (Ab3) that are capable of binding the same epitope on the antigen as the Ab1 antibody. Evidence of this pathway includes a competitive assay between Ab1 and Ab3, since the Ab1 antibody and the Ab3 antibody compete for the same epitope of the antigen.

In the Ab1c pathway, the Ab1 antibody binds to the antigen to form a complex. This complex is itself an antigen, and is sometimes described herein as a "modified antigen" or second antigen. The complex may induce the production of anti-antigen antibody (Ab1c) that are capable of binding a different epitope on the antigen as that bound by the Ab1 antibody. Evidence of this pathway also includes a competitive assay, but comparing the inhibitory effect on Ab1c by antibodies that bind to different epitopes on the antigen or lack of inhibition with Ab1.

In addition to producing Ab3 and/or Ab1c, typically associated with a humoral immune response, the compositions of the present invention may also produce a therapeutic benefit by inducing a cellular immune response (cell mediated immunity), as in the Background section. Both the cellular and the humoral response
25 involve indirect mechanisms for altering the immunogenicity of the host.

Compositions of the present invention may also initiate direct mechanisms for killing undesirable cells such as cancer cells. For example, in antibody-dependent cell-mediated cytotoxicity (ADCC), an Ab1 antibody, bound through its Fab region to a pre-determined antigen, may bind to the Fc receptor of a lymphocyte through the Fc region of the Ab1 antibody. Such participation between an antibody and immune
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1 system cells produces an effector function that may lyse tumor cells, infectious
agents, and allogeneic cells. Other indirect mechanisms involve complement-
mediated cytotoxicity (CDC), apoptosis, (neutralization of immunosuppressive tumor-
associated antigens), induction of cytokines and/or chemokines, neutralization of
5 immunosuppressive molecules, and neutralization of anti-adhesion molecules, among
others.

As used herein, a comprehensive approach to providing a therapeutic benefit
involves one or more, or all, of the following: cellular immunity and the molecules
involved in its production; humoral immunity and the molecules involved in its
9 production; ADCC immunity and the molecules involved in its production; CDC
immunity and the molecules involved in its production; natural killer cells; and
cytokines and chemokines, and the molecules and cells involved in their production.
One skilled in the art will recognize that a beneficial immune response (and thereby
overcoming immunotolerance) may be determined by a number of ways. Activation
of the multiple arms of the immune systems may be determined, for example, by
measuring the pre- and post-treatment antigen specific immune response, or by
measuring the reduction or amelioration of tumor burden and/or tumor size, or by
determining an increased survival period.

Specific demonstrations of the induction of a beneficial immune response or
providing a therapeutic benefit would include one or more of the following:

1) a humoral response to the administered antibody (Ab1), including evidence
of HAMA and/or Ab2;

2) a humoral response to the antigen, including evidence of the appearance of
antigen-specific antibodies to the same and/or different epitopes on the antigen as
the epitope for the binding agent (e.g., Ab3 and/or Ab1c);
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3) antibody-dependent cytotoxicity, including evidence that post-injection sera
with an antigen-specific antibody titer mediates tumor killing when the sera is
incubated peripheral blood mononuclear cells and tumor cell targets relative to pre-
injection baseline serum;
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1 4) complement-dependent cytotoxicity, including evidence that post injection sera combined with complement-containing plasma kills tumor cell targets relative to pre-injection baseline serum;

5 5) natural killer cell activity, including enhanced tumor cell killing by peripheral blood mononuclear cells (containing NK cells) in post-injection blood samples taken prior to the appearance of a measurable antibody response to the TAA relative to pre-treatment peripheral blood mononuclear cells;

9 6) antigen-enhanced cytotoxicity, including enhanced tumor cell target killing by peripheral blood mononuclear cells (in the presence of TAA-positive tumor cells) relative to pre-administration levels; and

13 7) cellular immunity, including evidence of T cell proliferation or tumor cell lysis post-injection relative to pre-injection.

17 Further, evidence of a beneficial immune response may include demonstrating that the binding agent-antigen complex results in a more vigorous T cell proliferative response than the response to either the binding agent or the antigen alone (in post-treatment PBMC versus pre-treatment). One skilled in the art will also recognize that this battery of evidence demonstrates that the compositions and methods of the present invention induce multiple different immune system pathways, and that these various pathways have varying relative importance to a particular patient, depending on the individual's specific immune constitution.

IMMUNOGENICITY ENHANCERS

1. LOW DOSE

25 In accordance with the methods of the present invention, a composition comprising the binding agent may be administered in an amount sufficient to recognize and bind the antigen, such as a pre-determined tumor associated antigen (TAA), and more preferably a soluble multi-epitopic antigen. In a preferred
29 embodiment of the invention, the dosage is sufficient to generate or elicit a beneficial, and preferably an effective immune response against the antigen. See Example 17.

1 An immunologically or therapeutically effective or acceptable amount of binding
agent is an amount sufficient to bind a pre-determined antigen *in vivo or ex vivo*, and
is capable of eliciting an effective immune response to the antigen. The response
may inhibit or kill cells, e.g., tumor cells, that carry and present a newly accessible
5 epitope, thereby ameliorating or eliminating the disease or condition that produces
the antigen. The immune response may take the form of a humoral response, a cell-
mediated response, or both. In a preferred embodiment of the invention, the dosage
of the monoclonal antibody is less than the dosage required to produce ADCC or
9 CDC to the administered binding agent.

The concentration or dosage of the protein in the composition can vary widely,
e.g., from less than about .01% to about 15 to 20% by weight. As noted above, the
composition is administered in an amount sufficient to stimulate an immune response
against the antigen. Amounts effective for this use will depend in part on the
severity of the disease and the status of the patient's immune system. Generally, the
composition will include about 0.1 µg to about 2 mg or more of protein agent per
kilogram of body weight, more commonly dosages of about 1 µg to about 200 µg per
kilogram of body weight, recognized by those skilled in the art as comprising a low
dose. Further, those skilled in the art will recognize and be able to evaluate the
various considerations that may be used to determine a proper dose. The
concentration will usually be at least 0.5%; any amount may be selected primarily
based on fluid volume, viscosity, antigenicity, etc., in accordance with the particular
mode of administration.

A method and composition of an embodiment of the invention includes a
composition comprising a low dose of a binding agent, wherein low dose refers to an
25 amount less than about 2 mg/kg of body weight, even more preferably, between
about 0.1 µg to about 2 mg per kilogram of body weight, and wherein the
administration of the composition comprising a low dose of binding agent induces a
beneficial immune response.

29 2. PHOTOACTIVATION

1 In accordance with the present invention, an antibody may be photoactivated.

In some embodiments, the present invention is directed to preparing antibodies using UV light so that the immunogenicity of the whole antibody is increased. As used herein, increasing the immunogenicity refers to increasing the recognition and/or response of an anti-idiotypic and/or anti-isotypic antibody. In a most preferred embodiment of the invention, the method increases the immunogenicity of the immunogen without altering or adversely affecting its antigenicity.

9 In accordance with the present invention, it may be beneficial to generate an enhanced response in order to produce a therapeutic benefit. For example, in accordance with the present invention, it may be desirable to administer UV-exposed antibodies to a cancer patient, with the specific purpose of generating an immune response (i.e., producing anti-idiotypic antibodies) to the UV-exposed antibody. This response may provide a therapeutic advantage via the humoral and cellular consequences directed to the cancer cells. In accordance with one aspect of the invention, the UV-exposed protein exhibits increased immunogenicity and therefore may be useful as a therapeutic for a disease.

The protein alteration processes of the present invention result in a modified protein with enhanced immunogenic potential. Perhaps the hydrophobicity/hydrophilicity has been altered by minor tryptophan disruption in combination with sulfhydryl generation to enhance its recognition/response by the immune cells. It is further possible that the antibody's constant portion has key amino acid specific changes which enhance Fc-mediated antigen presenting cell recognition. This is not related to changes in the polymeric state of the protein whereby aggregated forms (as have been observed for human immunoglobulins after UV exposure) are directed to phagocytic cells, since the photoactivated product maintains its monomeric state. The final extent of presentation and response of the antibody/antigen complex typically improve as a result of photoactivation, as detected by the HAMA response of antigen-positive patients injected with the photoactivated antibody.

1 Processes for photoactivating a binding agent are extremely well known in the
art, and include exposing the antibody to radiation, wherein the resulting altered
antibody is capable of generating an immune response when administered to an
animal typically capable of generating an immune response to the native form of the
5 antibody.

In a preferred embodiment of the invention, the antibody is exposed to
ultraviolet light. Typically, the antibody may be exposed to ultraviolet light at a
wavelength from about 200 nm to about 400 nm, at from about .1 to about 1000
9 Joules/cm², for from about 1 to about 180 minutes (more preferably, about 10 to
about 30 minutes). Tests run under these conditions show that the process typically
results in an intact or whole antibody that has been activated. These tests suggest
that the process according to the invention generates sulfhydryls between the light
and heavy chains of the antibody.

13 3. DELIVERY SYSTEM

17 Since some binding agents such as proteins are by themselves poor
immunogens, their immunogenicity may be augmented by administration in
immunological adjuvants and antigen delivery systems. The immunogenicity of a
specific composition may also be increased or optimized by choice of delivery route.
For example, the immunogenicity of compositions produced in accordance with the
present invention that include a monoclonal antibody may be increased by choosing a
mode of delivery that increases the direct contact between the binding agent and the
antigen. The preferred route is intravenous, more preferably without adjuvant. An
effective, but less preferred route is subcutaneous, more preferably with adjuvant.
25 Those skilled in the art are conversant with the various choices available, and why
one route might be chosen over another route for a particular binding agent.

29 One skilled in the art will also recognize that liposomes, nanospheres, micelles,
or microspheres may be used to administer a composition, and that such
administration may increase immunogenicity.

4. PHOTSENSITIZER

Compositions of the present invention may include one or more photosensitizers. Exemplary photosensitizers include, but are not limited to fluorescein, hematoporphyrin derivatives (e.g., Photofrin®), porphyrin derivatives, and perylenequinoid pigments. In a preferred embodiment of the invention, the photosensitizer comprises the use of perylenequinone (PQP) derivatives as photodynamic agents, and the use of PQP derivatives in immunophotodynamic therapy (IPT).

The invention also comprises a method of treating a disease by administering a therapeutically sufficient amount of at least one PQP derivative bound to a binding agent, and activating the conjugate, typically by photoactivating the PQP derivative. Typically, the PQP derivative may be activated by exposing the derivative to a pre-determined wavelength of light. The invention also includes a method of treating cancer which is enhanced in the presence of light wavelengths between about 400 nm and about 850 nm. Suitable PQPs include, but are not limited to those disclosed in U.S. Serial No. 08/782,048, incorporated herein by reference. In a preferred embodiment of the invention, the PQP is hypocrellin B, molecules derived from HB, and compositions that include HB or one or more of its derivatives.

The desired characteristics for a PDT sensitizer comprise at least one or more of the following characteristics: good absorption of light in a wavelength that penetrates tissue to the desired depth (absorption in the 600 nm to 850 nm range penetrate the skin many millimeters), compound sensitive to pH - inactive, lower activity or activity destroyed at the pH characteristic of normal tissues, but active or higher activity at the pH of the cells or organisms to be treated; compound cleared from the body quickly and if a compound is intended to treat solid tumors it should have the ability to function either in the presence and/or absence of oxygen to address the problem of tumor cell hypoxia. The photosensitizer should have low dark cytotoxicity, and excellent photopotential of cellular damage. The PDT toxic effect may be mediated via necrotic, apoptotic cell death, or by stasis of the tumor vasculature or vascular bed.

5. EFFECTORS

The present invention includes a composition comprising a binding agent bound to or used in conjunction with one or more effectors. As used herein, effector refers to a substance that affects the activity of the binding agent without binding to the substrate (or antigen) binding site.

A conceptually straightforward method to functionalize recombinant antibodies consists of sequentially fusing the antibody gene with the gene of a second protein, and expressing the resulting fusion protein as a single protein. Exemplary second proteins include but are not limited to:

a. A signal amplification moiety, such as a biotin mimetic sequence, which can be introduced at the C-terminus of a binding agent as a detection tag because of strong affinity of streptavidin-biotin;

b. Liposomes: fusion of certain amino acid sequences (with negative charges under physiologic condition) with a binding agent, such as single chain Fv-B43.13. Therefore, the fusion protein can easily be trapped by liposomes;

c. Cytokine sequences (e.g. IL-2): IL2 is a lymphokine synthesized and secreted primarily by T helper lymphocytes which have been activated by stimulation of the T cell receptor complex with antigen/MHC complexes on the surfaces of antigen-presenting cells. The response of T helper cells to activation is induction of the expression of IL2 and of IL2 receptors. IL2 possesses a variety of other activities which affect B cell growth and differentiation, formation of LAK cells, and augmentation of NK cells and enhancement of their cytolytic activity. Because of the central role of the IL2/IL2 receptor system in mediation of the immune response, it is obvious that manipulation of this system has important therapeutic implications. IL2 has already shown promise as an anti-cancer drug by its ability to stimulate the proliferation and activities of tumor attacking LAK and TIL cells.

d. Toxin: immunotoxins made by attaching a toxin (e.g. Pseudomonas extoxin and bacteria RNase) to the antibody or antibody fragments to produce cytotoxic molecules that selectively kill target tumor cell.

1 e. Enzyme: an antibody-directed enzyme pro-drug therapy system is a
particularly attractive artificial effector method. In this approach, an antibody is used
to target an enzyme to the tumor, and to retain it while the antibody-enzyme
conjugate clears from normal tissues. A non-toxic pro-drug is then administrated, and
5 this is activated by the enzyme to produce a cytotoxic drug at the tumor site.

f. Radionuclide chelator: any peptide that binds to a radionuclide chelator,
e.g., metallothionein (MT). MT is a ubiquitous, low-molecular weight, metal-binding
protein that participates in metal metabolism and detoxification. Mammalian forms of
9 MT bind seven ions in tetrahedral metal-thiolate clusters, including technetium and
other metals useful for targeted radiodiagnosis or therapy.

g. A phagocytosis enhancer, e.g., tuftsin. Tuftsin is natural tetrapeptide (Thr-
Lys-Pro-Arg) that was found to manifest several biological activities, including
activation of macrophages/monocytes and stimulation of phagocytosis. It has a wide
spectrum of immunoadjuvant activities which it exerts on the phagocytic cells, the
polymorphonuclear leukocyte, the monocyte and the macrophage. In animal and
clinical studies, tuftsin has displayed anti-tumor and anti-infection activity with no
detectable toxicity.

The fusion protein scFv-tuftsin was defined as a recombinant fusion protein
that is composed scFv antibody binding domain connected with tuftsin by an
artificial linker. This bi-functional protein was designed to achieve higher specific
anti-idiotypic immunogenicity.

METHOD

25 In an embodiment of the invention, MAb B43.13, directed against a first
epitope on the multi-epitopic antigen CA 125, induces an immune response against
CA 125 through one or more second epitopes on the CA 125 antigen. In a preferred
embodiment of the invention, any of the second epitopes are cryptic or previously
29 inaccessible epitopes that are exposed or available for interacting with a component
of the immune system reaction after MAb B43.13 binds to the antigen. Cryptic or

1 previously inaccessible refers to an epitope or binding site on the pre-determined antigen that does not activate or stimulate the immune system when the antigen is unbound by a binding agent according to the invention.

As used herein, "administering" refers to any action that results in exposing or
5 contacting a composition containing a binding agent with a pre-determined cell, cells, or tissue, typically mammalian. As used herein, administering may be conducted *in vivo*, *in vitro*, or *ex vivo*. For example, a composition may be administered by injection or through an endoscope. Administering also includes the direct application
9 to cells of a composition according to the present invention. For example, during the course of surgery, tumor cells may be exposed. In accordance with an embodiment of the invention, these exposed cells (or tumors) may be exposed directly to a composition of the present invention, e.g., by washing or irrigating the surgical site and/or the cells.

For diseases that can be characterized in part by having a tumor-associated antigen that is multi-epitopic, one embodiment of the present invention involves contacting a soluble antigen with a binding reagent (BA) that specifically binds to a single epitope on the multi-epitopic tumor-associated antigen.

In accordance with a method of the invention, the binding agent must be capable of binding a pre-determined binding site or receptor, and may be administered to the patient by any immunologically suitable route. For example, the binding agent may be introduced into the patient by an intravenous, subcutaneous, intraperitoneal, intrathecal, intravesical, intradermal, intramuscular, or intralymphatic routes. The composition may be in solution, tablet, aerosol, or multi-phase formulation forms. Liposomes, long-circulating liposomes, immunoliposomes,
25 biodegradable microspheres, micelles, or the like may also be used as a carrier, vehicle, or delivery system. Furthermore, using *ex vivo* procedures well known in the art, blood or serum from the patient may be removed from the patient; optionally, it may be desirable to purify the antigen in the patient's blood; the blood
29 or serum may then be mixed with a composition that includes a binding agent according to the invention; and the treated blood or serum is returned to the patient.

1 The clinician may compare the anti-idiotypic and anti-isotypic responses associated
with these different routes in determining the most effective route of administration.
The invention should not be limited to any particular method of introducing the
binding agent into the patient.

5 Administration may be once, more than once, and over a prolonged period.
As the compositions of this invention may be used for patient's in a serious disease
state, i.e., life-threatening or potentially life-threatening, excesses of the binding agent
may be administered if desirable. Actual methods and protocols for administering
9 pharmaceutical compositions, including dilution techniques for injections of the
present compositions, are well known or will be apparent to one skilled in the art.
Some of these methods and protocols are described in *Remington's Pharmaceutical
Science*, Mack Publishing Co. (1982).

A binding agent may be administered in combination with other binding
agents, or may be administered in combination with other treatment protocols or
agents, e.g., chemotherapeutic agents.

The effectiveness of the proteins of the present invention may be monitored *in
vitro* or *in vivo*. Humoral responses may be monitored *in vitro* by conventional
immunoassays, where the anti-tumor activity of the response may be determined by
complement-mediated cytotoxicity and/or antibody-dependent cellular cytotoxicity
(ADCC) assays. The assay methodologies are well known, and are described in
Handbook of Experimental Immunology, Vol. 2, Blackwell Scientific Publications, Oxford
(1986). Other assays may be directed to determining the level of the antigen in the
patient or tissue. Cell-mediated immunity may be monitored *in vivo* by the
development of delayed-type hypersensitivity reactions, or other *in vivo* or *in vitro*
25 means known to those skilled in the art, including but not limited to the skin test
reaction protocol, lymphocyte stimulation assays, measuring the toxicity of a subject's
lymphocytes to tumor cells by using a standard cytotoxicity assay, by a limiting
dilution assay, or by measuring plasma levels of cytokines using standard ELISA
29 assays.

Determining the effectiveness of a specific binding agent – antigen pair may also be accomplished by monitoring cell killing. Those skilled in the art will recognize that there are a variety of mechanisms that are proof of cell killing. As shown in the Examples, cell killing may be demonstrated by showing that Ab3 mediates ADCC, that Ab1 and HAMA mediates CDC, that natural killer (NK) cells are produced, and/or that cytotoxic T lymphocytes (CTLs) are produced.

EXAMPLES

Example 1. Antibody mediated immunotherapy influence of circulating antigen in inducing antigen specific anti-tumor immune responses.

This example demonstrates the use of antigen-specific murine monoclonal antibodies to induce an immune response against an immune-suppressive tumor-associated antigen. Injecting an antibody against a specific epitope in a multi-epitopic antigen can lead to immune responses against various other epitopes on this antigen.

In an attempt to understand the mechanism of action of MAb-B43.13, various immunological parameters were studied in ovarian cancer patients injected with this antibody. These studies clearly demonstrated activation of both the humoral and cellular anti-cancer immune responses.

The generation of human CA125-binding antibodies was measured before MAb-B43.13 injection and correlated to pre-injection CA125 levels as well as to survival data. Table 1 shows that generation of anti-CA125 antibodies correlates with CA125 pre-injection levels. Circulating CA125 affects the development of anti-CA125 antibodies only when patients received the MAb-B43.13 injection. If anti-CA125 antibodies before injection of MAb-B43.13 are compared between patients with low or high CA125 values (below or above 105 U/mL), no difference was found between the two groups (Table 1). A minimum concentration of 105 U/mL of CA125 was chosen as representing a significant amount of CA 125.

Tumor killing either through an anti-CA125 antibody-mediated ADCC mechanism or through CA125-specific CLTs, lead to increased survival in patients

1 injected with MAb-B43.13. Although high levels of serum CA125 have been
suggested to be a poor prognostic indicator, they seem to have a beneficial effect in
combination with the injection of anti-CA125 antibody in such patients. For example,
when the CA125 levels were more than 105 units/mL, immune response against CA
5 125 increased by more than 20% which in turn increased the median survival in those
patients from 39.1 months to 54.5 months (Table 1). Thus the injection of a binding
agent to a patient containing elevated levels of multi-epitopic soluble antigen leads to
antigen specific humoral and cellular response which in turn leads to tumor killing
9 followed by improved survival.

TABLE 1: Correlation between Serum CA125 Levels, Human Anti-CA125 (Ab₁)
Response and Survival in Patients Injected with MAb-B43.13

Preinjection Serum CA125 Level	%-age of Patients with Human Anti- CA125 Response	Mean Survival in Month
<105 U/mL	10.3%	39.1
>105 U/mL	32.6%	54.5

TABLE 2: Correlation between Serum CA125 Levels and Antibody Levels in Patients
Injected with MAb-B43.13.

Pre-injection Serum CA125 Level	Anti-CA125 Antibody Titre (No. of Positive/Total Patients)
<105 U/mL	3/29
>105 U/mL	15/46

- 1 The correlation between CA125 antibodies and survival, with a CA 125 cut-off of 105 U/ml is shown in Table 3.

Table 3

anti-CA125 Antibodies

mean \pm SD

	n	[ng/ml]	P	[-fold increase]	P	mean \pm SD [months]	Survival median	P
Anti-CA125 Non-Responders	27	61.8 \pm 25.1	0.0031	1.3 \pm 0.7	<0.0001	34.8 \pm 18.2	34.0	<0.0001
Anti-CA125 Responders	20	346.4 \pm 376.3		7.4 \pm 5.1		67.6 \pm 27.0	67.0	
CA125<105 U/ml	19	94.0 \pm 61.0	0.0213	2.4 \pm 1.3	0.0089	46.1 \pm 26.8	40.5	0.7369
CA125>105 U/ml	28	239.8 \pm 308.8		5.3 \pm 5.2		50.5 \pm 28.3	44.5	
Anti-CA125 Non-Responders								
CA125<105 U/ml	12	53.8 \pm 12.0	0.1146	1.6 \pm 0.7	0.8448	38.5 \pm 23.5	37.5	0.4945
CA125>105 U/ml	15	68.2 \pm 31.0		1.5 \pm 0.7		31.8 \pm 12.6	30.0	
Anti-CA125 Responders								
CA125<105 U/ml	7	162.9 \pm 46.1	0.0152	3.9 \pm 0.4	0.0009	51.9 \pm 24.0	45.0	0.0572
CA125>105 U/ml	13	445.2 \pm 357.8		9.6 \pm 4.7		76.0 \pm 25.4	82.0	
CA125<105 U/ml								
Anti-CA125 Non-Responders	12	53.8 \pm 12.0	0.0006	1.6 \pm 0.7	<0.0001	38.5 \pm 23.5	37.5	0.2718
Anti-CA125 Responders	7	162.9 \pm 46.1		3.9 \pm 0.4		51.9 \pm 24.0	45.0	
CA125>105 U/ml								
Anti-CA125 Non-Responders	15	68.2 \pm 31.0	0.0025	1.5 \pm 0.7	<0.0001	31.8 \pm 12.6	30.0	<0.0001
Anti-CA125 Responders	13	445.2 \pm 357.8		9.6 \pm 4.7		76.0 \pm 25.4	82.0	

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1 In an attempt to understand the mechanism behind anti-CA125 antibody
formation by MAb-B43.13 injection in cancer patients, we characterized the human
anti-CA125 antibodies present in their sera. For example, if the anti-CA125 antibodies
were generated in the manner suggested by the idiotypic network, MAb-B43.13
5 would generate anti-MAb-B43.13 antibodies, some of which would exactly mimic the
CA125 antigen (=Ab2 β). These in turn can generate anti-CA125 antibodies (=Ab3).
The Ab3 generated through this pathway would bind to the same epitope on CA125
as the Ab1 (=B43.13) and therefore compete with the binding of MAb-B43.13 to the
9 antigen.

On the other hand, antibodies generated through the antigen itself will bind to
various epitopes available on the antigen. If the anti-CA125 antibodies were
generated in a manner suggested by the present invention, the pathway would follow
Ab1 + soluble antigen \rightarrow Ab1c. Following this scheme, MAb-B43.13 (Ab1) would
bind the CA125 serum antigen, which would in turn generate an anti-CA125
antibody (Ab1c). Furthermore, the Ab1c antibodies generated under this pathway
would bind and be inhibited by other anti-CA 125 antibodies, such as B27.1 or M11,
because, as noted above, CA125 is multi-epitopic and B43.13, M11, and B27.1 epitopes
are distinct. Also, Ab1c will not bind to anti-MAb-B43.13 antibodies.

Analysis of the serum samples with positive anti-CA125 titer demonstrated
that their binding to CA125 could be inhibited not only by MAb-B43.13 single chain
antibody but also by F(ab') fragments of other anti-CA125 antibodies, B27.1 and M11,
that recognize epitopes on CA125 which are different from B43.13 (Tables 3 and 4).
Sera from only two patients were considered to contain anti-CA125 antibodies that
were exclusively generated via idiotype induction of MAb-B43.13 (=Ab3) i.e. anti-
25 CA125 antibodies that could only and completely be inhibited with MAb-B43.13 and
bound to polyclonal rabbit Ab2.

Thus, if the patients serum contained anti-CA125 antibodies that were
inhibitable by MAb-B43.13 only, it was classified as containing Ab3; those inhibitable
29 by MAb-B27.1 were classified as Ab1c. In other words, injecting a binding agent

1 such as an antibody against a single epitope on a multi-epitopic antigen leads to
generation of a humoral and cellular response against a different epitope on the
antigen.

5 The presence of a multi-epitopic anti-CA125 response in sera of MAb-B43.13
treated patients with high CA125 levels make us believe that, besides anti-idiotypic
induction, other mechanisms exist to induce an immune response against tumor-
associated antigens. In this scenario, the injected antibody forms a complex with the
circulating antigen *in vivo*. This process can cause several effects. The complexation
9 of the antigen by antibodies can facilitate the uptake of CA125 by professional
antigen-presenting cells (APC) and thus render the antigen more immunogenic. The
complexing antibody -- in our case from a murine source -- could also function as an
adjuvant, adding a foreign component to the self-antigen CA125 that might facilitate
recognition by the immune system. Epitopes of the antigen are blocked by the
complexing antibody and are either protected from processing or processed at
different sequences thus creating new peptides for MHC-binding. It is also possible
that a conformational change in the antigen takes place upon antibody binding
thereby exposing new epitopes to the immune system, including sub-dominant or
immune-dormant epitopes.

13 It is interesting to note that the complex formation between CA125 and MAb-
B43.13 has also been observed during pharmacokinetic studies, as determined by
drop in circulating CA125 levels upon injection of MAb-B43.13. When patients
received more than one injection and patients developed high amounts of human
anti-mouse antibodies (HAMA), the antibody showed rapid clearance to liver and
spleen, as demonstrated in immunoscintigraphic studies. Antigen-antibody
25 complexes, accumulated in lymphoid centers like the spleen, are known to be very
efficiently presented to T cells by antigen-presenting cells, such as B cells,
macrophages, or dendritic cells.

29 Augmentation of antigen processing and presentation by immune complexing
has been demonstrated in several systems. Targeting tetanus toxoid to FcγR by

1 complexing with anti-tetanus toxoid IgG results in a 10-1000-fold increase in
processing and presentation of this antigen as measured by T_H cell activation. A
similar increase in immunogenicity was observed with hepatitis B antigen complexed
with its corresponding antibody. Also the natural presence of antibodies against α -
5 galactosyl epitopes has been used to augment tumor vaccine immunogenicity in α -
galactosyl -modified tumor-associated antigens.

It was observed that MAb-B43.13 has a protective effect on its CA125 epitope
during antigen processing by the immune system. The MAb-B43.13 epitope was
9 recognized by almost all anti-CA125 antibody samples from patients (inhibition in
78% of the samples, Table 4).

The reverse seems to be true as well, i.e. CA125 has conserving properties on
the idiotope of MAb-B43.13 during the antigen processing event. The increased
formation of Ab2 in mice immunized with the CA125-MAb-B43.13 complex compared
to mice immunized with MAb-B43.13-KLH (Figure 3) and the increased Ab2
production in MAb-B43.13 injected patients with CA125 titers above 105 U/mL
confirm this observation. See Table 4 and Figure 6 for a summary and Table 5 for
the details of these results. Sera from these patients were analyzed for the presence
of human anti-CA125 antibodies by their ability to bind to CA125 [R. Madiyalakan et
al, *Hybridoma*, 14:199-203 1995) and Schultes et al., *Cancer Immunology and*
Immunotherapy 46:201-212 (1998)]. Antibody purified from pooled patients' sera were
found to inhibit B43.13 in similar assays, but not B27.1. The explanation for this
anomaly is yet to be determined. However, it has been confirmed using M11
antibodies that B43.13 binds to a distinct epitope, and that upon binding with B43.13,
CA 125 is in fact recognized by the immune system.

Table 4

Inhibition			
No. of Positives/Total			
(%)			
CA125	B43.13 scFv	B27.1 F(ab')	M11 F(ab')
10500 U/ml	1 μ g/ml	1 μ g/ml	1 μ g/mL
26/28	22/28	11/28	8/19
(92.8)	(78.6)	(39.3)	(42.1)

1 **TABLE 5: Characterization of Anti-CA125 Antibodies in Patients Injected with MAb-B43.13**

Patient	Inj #	days post- inj.	Anti- CA125 Ab levels (ng/mL)	Binding to anti-MAb B43-13 (AB2)†	Inhibition (%) ¹				Classification
					CA125 10000 U/mL	B43.13 ScFv ² 10 µg/mL	B27.1 F(ab') ² 1 µg/mL	M11 F(ab') ² 1 µg/mL	
1	3	0	14.8	+	62.3	42.6	5.8	2.3	Ab3
2	1	185	9.5	--	21.6	-46.9 ³	-86.9 ³	24.3	Ab1c
3	2	239	45.4	+	89.7	95.3	12	ND	Ab3
	3	86	25.4	+	80.2	84.4	-05 ³	2.1	Ab3
	3	207	48.7	+	91.4	94.0	-9.1 ³	ND	Ab3
	4	144	79.7	+	77.1	93.0	3.5	4.5	Ab3
	4	270	30.9	+	79.2	83.0	-55.8 ³	ND	Ab3
	4	309	16.7	+	77.0	83.0	-55.8 ³	ND	Ab3
4	5	45	16.0	+	51.6	50.9	34.8	ND	Ab3/Ab1c
	5	134	64.1	+	89.1	83.3	-37.3 ³	-2.3	Ab3
	2	15	23.6	-	62.3	-84.8 ³	-101.9 ³	18.5	Ab1c
5	2	41	21.6	-	56.9	20.2	-7.0 ³	ND	Ab1c
	2	76	23.1	-	63.6	29.4	4.5	ND	Ab1c
	3	28	11.1	--	24.2	4.7	11.1	35.6	Ab1c
5	1	16	15.5	+	74.8	78.3	39.9	-12.5	Ab1c/Ab3

Patient	Inj #	days post- inj.	Anti- CA125 Ab levels (ng/mL)	Binding to anti-MAB B43-13 (AB2) [†]	Inhibition (%) ¹				Classification
					CA125 10000 U/mL	B43.13 ScFv ² 10 µg/mL	B27.1 F(ab') ² 1 µg/mL	M11 F(ab') ² 1 µg/mL	
6	3	0	10.3	+	54.0	60.2	22.7	1.5	Ab1c/Ab3
7	3	0	14.9	--	29.7	-70.2 ³	-358.9 ³	ND	Ab1c
8	3	7	59.1	--	77.1	87.1	34.9	12.5	Ab1c
	3	17	46.9	-	78.4	86.5	40.7	9.6	Ab1c
9	3	112	9.2	-	-66.4 ³	16.0	20.2	45.6	Ab1c
	3	166	8.5	-	-18.4 ³	42.5	56.5	33.8	Ab1c
10	3	0	41.5	--	30.8	39.2	20.0	57.8	Ab1c
11	5	134	8.8	-	19.0	24.4	3.5	-6.5	Ab1c
	6	134	8.7	-	18.0	39.0	46.0	ND	Ab1c
	9	26	13.4	-	54.5	19.3	11.1	ND	Ab1c
	9	65	13.3	-	56.1	24.4	3.7	ND	Ab1c
	10	40	9.4	--	61.4	37.0	33.4	2.3	Ab1c
12	2	14	10.6	-	24.5	-54.4 ³	19.9	65.8	Ab1c
13	1	15	11.5	-	30.8	47.4	55.8	2.5	Ab1c
14	2	17	10.1	-	30.3	-51.2 ³	1.2	32.4	Ab1c

¹ To be considered to be significant, inhibition has to be at least 15%

² Single chain MAb-B43.13, F(ab') MAb-B27.1, and F(ab') M11 were used in the inhibition studies to avoid non-specific inhibition due to the Fc portion of the antibody and cross-reactivity due to HAMA.

³ This experiment produced an anomalous result, as evidenced by the negative number, the reasons for which have yet to be determined.

† Anti-MAb-B43.13 (Ab2) was purified from rabbits injected with MabB43.13.

ND = not determined. NA = not applicable

Therefore, complex formation can lead to enhanced anti-CA125 as well as anti-idiotypic antibody formation. Manca et al., *J. Immunol.* **140**:2893 (1988) and Ling et al., *Immunology* **62**:7 (1987) have shown that antibodies can preserve the sequence of their epitope during antigen-processing and antibodies have been used to raise immune responses to less immunogenic epitopes of an antigen.

Enhanced antigen-presentation of antigen-antibody complexes was attributed to facilitated antigen uptake via the Fcγ-receptor (macrophages, dendritic cells) or membrane-bound Ig (B cells) on professional antigen-presenting cells (APC). The human FcγRI and RIII-receptor on macrophages and dendritic cells does not bind murine IgG₁, but the human FcγRII, which mediates phagocytosis and pinocytosis of small immune complexes, has strong affinity to this murine IgG isotype. Accordingly, various professional APC can be involved in the preferential presentation of the CA125-MAb-B43.13 complex. We tested B cells with two different specificities as well as macrophages as APC: CA125-specific B cells (from mice immunized with CA125) and anti-MAb-B43.13-specific B cells (from mice immunized with MAb-B43.13). Normal B cells served as control. When the proliferation of CA125-specific T cells was monitored by [methyl-³H]-Thymidine uptake, optimal stimulation was observed in MAb-B43.13 specific B cells, primed with the CA125-MAb-B43.13 complex (Figure 3), followed by presentation of CA125 by CA125-specific B cells. Enhanced presentation of immune complexes by macrophages and dendritic cells is mediated by preferential uptake via the FcγR. Figure 4 confirms that CA125 is presented more efficiently by macrophages, if complexed with an antigen specific antibody.

1 The ability of MAb B43.13 to increase the immunogenicity of CA 125 was
studied in a mouse model by immunizing a mouse with the CA 125-MAb 43.13
complex, compared to CA125 or MAb B43.13 alone as the immunogen. When the
mouse sera was analyzed for anti-CA125 antibody levels, the mice injected with the
5 antigen-antibody complex had the highest titers (see Figure 5). This supports the
observation that interaction of the antigen with a specific antibody leads to a higher
antigen specific humoral immune response compared to antibody or antigen alone.

9 These results clearly indicate that when an antibody against a single epitope
(B43.13) was injected into a patient, an antibody response against the whole antigen is
generated which recognizes different epitopes present in the antigen. In other words,
injecting a binding agent such as a monoclonal antibody to a soluble multi-epitopic
antigen into a patient having a functioning immune system generates an antibody to
the antigen, where the generated antibody is inhibited by antibodies to different
epitopes.

Example 2.

17 Similarly, injecting the binding agent to the cancer patients having circulating
CA125 lead to antigen specific CTL's. Peripheral Blood Mononuclear Cells (PBMC)
from eight patients injected with MAb-B43.13 were tested for cytotoxicity against
CA125 positive or CA125 negative ovarian tumor cells in a chromium release assay.
21 The results are shown in Table 6. The specificity of the lysis was confirmed by the
ability of MAb-B43.13 to inhibit such lysis, as well as the inability to kill CA125
negative tumor cells. Of the 8 patients who received MAb-B43.13, at least four
patients (#5 to #8) were determined to have CA125 specific cytotoxic T lymphocytes
25 (CTL's) in their blood. The generation of CA125 specific CTL's are likely to kill
ovarian tumor cells in patients.

TABLE 6: Cytotoxicity In Patients Injected With A Vaccine Containing MAb-B43.13

PATIENT ID	SAMPLE		PERCENT LYSIS			PERCENT INHIBITION BY MAb-B43.13 (5 µg)	PERCENT DIFFERENCE BETWEEN CA 125 positive and CA 125 negative CELLS
	Injection Number	Days Post Injection	CAOV-4	SK-OV-3	K562		
1	2	17	2.0	0.0	3.7	ND*	insignificant
2	2	0	9.8	7.5	33.5	ND	31
3	3	0	22.8	20.4	64.3	ND	12
4	3	0	25.8	20.2	44.5	4.7	28
5	3	0	65.1	45.4	80.7	ND	43
6	3	0	23.1	20.0	42.0	19.2	16
	3	6	7.4	5.2	10.2	53.0	42
7	4	355	10.3	3.1	18.9	ND	23
8	10	425	25.5	18.2	39.2	15.4	40

*ND = Not Done due to lack of sufficient lymphocytes

Results are the mean of one experiment performed in triplicate

Example 3. Immunotherapy of human ovarian carcinoma in an animal model

In order to investigate the therapeutic effectiveness, MAb-B43.13 was tested in a human-PBL-SCID/BG mouse model. Mice were reconstituted with human-PBL(normal donors) by i.p. injection of 2 to 3×10^7 PBL/mouse. MAb-B43.13 was administered at $100 \mu\text{g}/\text{mouse}$ in PBS, in different experimental set-ups. An isotype matched control antibody (MOPC21 or MAb-170) and PBS injection served as controls. The ovarian cancer cells NIH: OVCAR-Nu3 were injected i.p. at 1×10^6 cells/mouse or s.c. at 4×10^6 cells/mouse. Hu-PBL-SCID/BG mice were either immunized before injection of tumor cells, or after small tumors were established (two weeks after transplantation). In another experiment, tumor-bearing mice (s.c.)

1 were injected with MAb-B43.13 two weeks after tumor transplantation, along with
PBL .

Antibody injections were repeated twice in 2-week intervals. Functional and
cellular characterization of serum and PBL from these mice demonstrated the
5 successful engraftment of a human immune system in those mice.

All three experiments showed that MAb-B43.13 treatment could: a) delay or
prevent development of tumors; b) reduce the size of small, established tumors (s.c.
tumor injection) or suppress ascites production; c) delay tumor growth when injected
9 prior to tumor implantation and d) prolong the survival of mice (i.p. tumor injection).

Human tumor infiltrating lymphocytes (TIL) were identified in mice using
flow cytometry, which might contribute to the in vivo anti-tumor activity of MAb-
B43.13.

At the endpoints of the therapy study, surviving mice from different treatment
groups were euthanized. Blood, spleen, tumor, and peritoneal washes were obtained
form the measurement of human immunoglobulin as well as flow cytometric analysis
of human PBL in mouse tissues. Tumors were also analyzed by
immunohistochemistry.

Example 5. Induction of idiotypic network to anti-MUC-1 antibody in breast cancer.

21 MUC-1 proteins (polymorphic epithelial mucin) expressed on malignant
epithelium are under-glycosylated, which leads to exposure of novel T and B cell
epitopes. An anti-MUC-1 murine clone, Alt-1, was generated by immunization of
mice with CA15.3 antigen, a glycoprotein consisting of an MUC-1 protein and
25 carbohydrate, and characterized for its binding specificity to CA15.3 by ELISA and to
MUC-1 transfectoma by FACS analysis. Injection of MAb-Alt-1 (Ab1) conjugated to
KLH into mice carrying MUC-1 transfectoma resulted in anti-idiotypic antibody
(Ab2) (Figure 7) and anti-anti-idiotypic antibody (Ab3) production (Figure 8) . A

1 minimum of four injections at a dose of 50 μ g/mouse resulted in a measurable
humoral response. The Ab2 and Ab3 levels reached their peak after six injections. The
anti-idiotypic antibody (Ab2) competed with the native antigen, CA15.3. T-cell
proliferation studies showed specific response to the injected antibody and CA15.3
5 indicating the presence of idiotype specific T-cells (T2) and anti-idiotypic specific T
cells (T3).

In addition, a breast tumor model was developed using a human MUC-1 gene
transfected mouse mammary carcinoma, 413BCR. Groups of mice were treated with
9 Alt-1-KLH or human immunoglobulin conjugate, and compared to appropriate
positive control (liposomal MUC-1) and negative control (murine immunoglobulin).
Immunizations were performed twice before or after tumor implantation at weekly
intervals. The tumor volumes were measured weekly and the growth rates assessed.

A significant tumor reduction was observed in mice treated with Alt-1-IgG
conjugate compared to other groups.

Example 6.

17 A composition according to the invention was produced against CA 19.9
(SLe^a), an excellent marker for pancreatic cancer (87%), gastric cancer (68%), and colo-
rectal cancer (50%). It has been documented that the carbohydrate ligand (SLe^a)
constitutes the carbohydrate moieties of the human carcinoembryonic antigen
family [Anostario, et al; 1994]), human pancreatic MUC-1 [Ho, et al; 1995]), and CA
21 19.9 [Hamanaka, et al; *Pancreas*, 13:160-165 (1996)]. SLe^a has also been identified in
human melanoma [Ravindranath, et al, *Cancer*, 79:1686 (1997)] and colorectal cancer
[Yamada, et al (1997)]. Those skilled in the art will recognize that a composition
25 containing a binding agent specific for SLe^a (or one or more other adhesion
molecules), such a composition optionally having one or more other binding agents
specific for other antigens or molecules, may be useful in the treatment of many other
cancers, since SLe^a is expressed in large quantities on the surface of many other
29 tumors [Srinivas, et al; (1996)].

1 The binding agent in the composition was Alt-3, an IgG3 monoclonal antibody
that binds strongly to CA 19.9, and has been shown to mediate tumor killing through
CDC *in vitro*.

5 Approximately 10^4 chromium labeled SW 1116 (2200 CPM) were incubated
with different concentrations of Alt-3, Alt-2, NS1116, Alt-4, and unspecific mIgG3 (20
 $\mu\text{g/mL}$ to $0.0025 \mu\text{g/mL}$). The antibodies were incubated for 45 minutes at 4°C . In
the treatment groups incubated with HAMA, the antibodies were washed twice with
medium and incubated with $1 \mu\text{g/mL}$ of HAMA for 45 minutes at 4°C . All plates
9 were washed and effector cells (fresh collected human PBLs) or fresh human serum
(20% in medium) were added and incubated for four hours. The cytotoxic index
(C.I.) was then calculated. Paired T test was used to analyze each concentration.

This experiment shows that Alt-3 and Alt-2 are extremely effective in
complement-mediated cytotoxicity (Figure 9). Such cytotoxicity is increased in the
presence of HAMA. The anti-tumor effect of Alt-3 was also analyzed in SCID/BG
mice reconstituted with human PBL. This experiment shows a reduction in tumor
volume as a result of the binding agent and the binding agent/antigen complex.
(Figure 10).

Example 7. PSA directed immunotherapy of prostate cancer (Production of AR47.47)

21 Prostate specific antigen (PSA) represents an attractive target for the
immunotherapy of prostate cancer. This glycoprotein is almost exclusively
synthesized by the prostatic gland and is currently used for the diagnosis and
monitoring of prostate cancer patients. However, since PSA is recognized as a self-
25 antigen, it is essential for effective immunotherapy to develop innovative strategies
capable of triggering the immune system and induce a protective immunity against
PSA expressing cells. This example demonstrates the use of an antibody to elicit an
anti-idiotypic cascade associated with an antigen specific anti-tumor immune
29 response. A large panel of anti-PSA monoclonal antibodies have been produced in

our laboratory and these antibodies were evaluated for their potential therapeutic efficacy against prostate cancer. We have demonstrated that the immunization of mice with a selected anti-PSA antibody can induce a specific immunity against PSA itself. These results therefore emphasize the potential use of anti-PSA antibodies for the immunotherapy of prostate cancer.

Hybridoma clones secreting anti-PSA antibodies were produced by fusion of the murine myeloma cells Sp2/O with the splenocytes of a Balb/c mouse immunized with human PSA. An exemplary clone, AR47.47, binds to an epitope of PSA corresponding to amino acid sequences 139-163 of the PSA molecule.

The first criteria of selection used to identify the anti-PSA antibody was the ability of this antibody to interact with circulating PSA. Circulating PSA is found either in a free form or complexed to anti-proteases such as α -anti-chymotrypsin and α 2-macroglobulin. To screen for clones we used three different forms of PSA: free PSA; PSA complexed to α -anti-chymotrypsin (PSA-ACT); and free PSA non complexing to α -anti-chymotrypsin (PSA-nc). Free PSA corresponds to PSA directly purified from human seminal fluid. Co-incubating free PSA with purified ACT results in the formation of PSA-ACT and PSA-nc. PSA-nc can be separated by gel filtration chromatography. It is believed that PSA-nc may represent the free form of PSA present in the circulation. Complexing of PSA with α 2-macroglobulin results in the total encapsulation of PSA. As a consequence, this form of PSA is no longer detectable by monoclonal anti-PSA antibodies. We therefore did not use this form of circulating PSA for the screening.

PSA belongs to the kallikrein family and a high degree of structural homology is found between PSA and the kallikreins HK1 and HK2. The absence of cross reactivity of the anti-PSA antibody with kallikrein isolated from human plasma was used as second criteria for selection.

The hybridoma clone AR47.47 responded to the criteria described above, a strong immunoreactivity was observed with the three forms of PSA used for the screening whereas no cross reactivity was observed with human plasmatic kallikrein.

1 The hybridoma clone AR47.47 was cloned twice by limiting dilution and the second
generation clone AR47.47R6R6 was chosen for further studies. Clone AR47.47R6R6
was adapted to standard medium (RPMI 10% FBS) and a cell bank was formed. The
absence of mycoplasma contamination was verified by using the Boehringer
5 Manheim mycoplasma test. Clone AR47.47R6R6 has been deposited in the American
Type Culture Collection, and has received Accession No. H-B 12526.

Immunization in DBA mice with a binding composition according to the
invention (AR47.47) was examined for the induction of a specific PSA immunity via
9 the idiotypic network (i.e. induction of Ab3 antibodies). Anti-PSA antibodies (Ab3)
could be detected in the serum of animals immunized with AR 47.47, a minimum of
two injections of AR 47.47 was required for Ab3 production. No reactivity towards
PSA was detected for the control groups (mice immunized with an isotype matched
control antibody not related to PSA and mice receiving PBS injections).

AR 47.47 is directed towards a PSA epitope comprised between the sequence
139-163 of the PSA molecule. The anti-PSA antibodies produced by AR 47.47
immunized mice can specifically interact with the PSA peptide 139-163, showing that
at least part of the Ab3 produced are identical in term of specificity to AR 47.47.
These results demonstrate that the immunization with AR 47.47 can induce a specific
anti-PSA immunity in the host.

21 **Example 8. Anti-idiotypic induction of PSA immunity in mice**

Mice were used to determine whether immunization with anti-PSA antibodies
can induce a specific immunity against PSA via activation of the idiotypic network.
The goal of this experiment was to demonstrate that the immunization of mice with
25 anti-PSA antibodies (Ab1) can stimulate the immune system to generate anti-idiotypic
antibodies (Ab2 =surrogate antigen), and anti- anti-idiotypic antibodies (Ab3) capable
of reacting with the original antigen.

These experiments used a commercially available antibody as a model anti--
29 PSA antibody (RLSD09; ATCC HB-8525). The purified antibody was conjugated to

1 Keyhole Limpet Hemocyanin (KLH) to enhance its immunogenicity. The anti-PSA
antibodies conjugated to KLH were still capable of binding to PSA, indicating that the
idiotype of the antibodies were not masked by the conjugation procedure. B43.13
antibody, a mouse monoclonal antibody of the same isotype as the PSA antibody
5 (IgG1) was used as the control. B43.13 antibody is specifically directed against the
CA125 ovarian tumor antigen and does not cross react with PSA. In addition FACS
analysis verified that the B43.13 antibody does not bind at the cell surface of Line-1-
PSA or P81 5-PSA.

9 Mice were subdivided into three groups of five mice each. The first group of
mice was immunized with anti-PSA antibody conjugated to KLH. The second group
of mice was immunized with the control B43.13 antibody conjugated to KLH. The
third group of mice received PBS injection. Injections were performed i.p. at 10 days
intervals with complete Freund adjuvant for the first injection and incomplete
Freund adjuvant for the second injection.

Ab2 is a surrogate antigen capable of mimicking the PSA epitope recognized
by the injected anti-PSA antibody. A competitive inhibition assay was established to
measure the serum level of Ab2. This assay was performed 5 days after the second
injection. An inhibition was observed after incubation in the presence of mouse sera
from mice immunized with anti-PSA antibody, but not when sera from mice
immunized with control antibody or PBS were used. These results indicate that the
immunization of Balb/c mice and DBA mice with the anti-PSA antibody can induce
the formation of anti-idiotypic antibody (Ab2) capable of mimicking PSA.

Example 9. Effect of Anti-PSA immunization on tumor development

25 Balb/c mice were used to determine whether immunization with anti-PSA
antibodies can protect the animals against a subsequent tumor challenge. Balb/c mice
were divided into 3 groups of 5 mice each. The first group was immunized with anti-
PSA antibody RLSD09 conjugated to KLH, the second group was immunized with
29 control antibody B43 conjugated with KLH, the third group received PBS injections.

1 A total of 4 injections were given for each group using 50 µg of antibodies for each
injection. The tumor cells Line-1-PSA were injected intravenously between the third
and fourth injections. Nineteen days after tumor inoculation, the mice were sacrificed,
the number of tumor foci in the lungs and Ab3 levels in the serum were determined.

5 The tumor burden in the group of mice immunized with anti-PSA MAb was
considerably lower compared to the group of mice immunized with control antibody.
Of particular interest is the demonstration, in the group of mice immunized with
anti-PSA MAb, of a negative correlation between Ab3 levels and the number of
9 tumor foci in the lungs.

Example 10. Anti-inflammatory composition.

To test for the effectiveness of a composition containing a binding agent in
treating inflammation, a double blind experiment was performed on 18 Sprague
Dawley rats (weight about 450g) divided into 3 groups (8 rats in each group).

The first group was vaccinated with KLH conjugated IgM antibody specific for
a carbohydrate ligand on leukocytes (250 µg/rat, i.p.). The second group was
vaccinated with KLH conjugated IgM antibody with no binding to the same ligand
(250 µg/rat, i.p.). The third group was a control group, and received no vaccination.

Inflammation was induced by injecting 1% carrageenan in 0.9% NaCl (type IV),
in the rat right hind paw (0.5 ml/rat). Observation of paw edema by water
displacement measurement and caliper measurement.

The inhibitory effect of Alt-4 antibody on inflammation was clinically different
from the control group and control IgM antibody group (Figure 11).

Example 11. Photoactivation increases immunogenicity

Normal, healthy, Sprague-Dawley rats were used. Animals were randomly
grouped (4 per group) to receive four different doses (5 µg, 10 µg, 25 µg and 50 µg) of
MAb 43.13. Pre-injection blood samples were drawn prior to initiation of the

1 injection schedule. Each rat received the appropriate dose of MAb diluted in sterile
0.01 M phosphate buffered saline intravenously. A second study group received 20
µg of each MAb preparation with or without Incomplete Freund's Adjuvant (IFA).
Blood samples were taken just prior to the dose injection at 0, 21, 42, 63 and 77 days.

5 MAb-B43.13 is a murine IgG, reactive with CA 125. Antibody preparations
consisted of MAb-B43.13 in the native form or in a UV-exposed form (e.g.,
photoactivated). Native MAb was diluted from a stock concentration of 5 mg/mL
with 0.01 M phosphate buffered saline to doses of 5, 10, 25 and 50 µg/100 µL. UV
9 exposed MAb was reconstituted from the lyophilized form with 0.01 M phosphate
buffered saline (2.2 mg/0.47 mL) and diluted to obtain the same doses as for the
native MAb.

An assay was developed to measure the rat anti-mouse response in the serum
of the injected animals. Anti-isotype rat anti-mouse antibodies were measured using
an ELISA plate coated with an isotype matched control antibody, MOPC 21. Samples
were diluted 1/100, allowed to react with the coated antibody, washed, and bound
antibody detected using peroxidase conjugated goat anti-rat IgG (H + L) with ABTS
substrate. Unknowns were read off a standard curve generated using a commercial
rat anti-mouse antibody.

The results of the rat anti-mouse (RTAMA) analysis of sera from the various
groups of rats injected with native and UV exposed MAb-B43.13 are shown in Tables
7 and Table 8. The immunological response to the preparations is expressed in terms
of the number of responders in each group, with the numerical cut-off defined in the
tables. This value (mean of all pre-injection samples (blanks) + 3 S.D.) ensures that a
true positive response is measured and the results are unlikely to be due to assay
25 variation. The tabulation of responders is probably more meaningful given that the
fluctuation of the magnitude of response can be very large and therefore, hinder
interpretation.

1

Table 7

**ANIMAL RESPONSE* TO INTRAVENOUS INJECTION OF NATIVE AND UV
EXPOSED MAb-B43.13 PREPARATIONS**

5

Sampling Time	Preparation	Number of Responders			
		5 µg	10 µg	25 µg	50 µg
Pre-injection (blank)	Native	NA**	NA	NA	NA
	UV exposed	NA	NA	NA	NA
Day 21	Native	0	0	0	0
	UV exposed	2	3	1	1
Day 42	Native	0	1	0	1
	UV exposed	2	3	4	3
Day 63	Native	1	3	3	3
	UV exposed	2	4	3	4
Day 77	Native	2	2	2	1
	UV exposed	3	4	4	4

9

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13

* Number of animals responding in a group of four (RTAMA values \geq pre-injection sample mean + 3 S.D.)

** NA = Not Applicable

17

The data tends to confirm that the response to the UV exposed MAb-B43.13 occurs earlier (after only one injection) as shown by the greater number of responders at all dose levels in the Day 21 groups.

Furthermore, at all other time periods (and after multiple injections), the proportional response of each group given intravenous UV exposed MAb-B43.13 is greater. It may be suggested that the response is sustained longer for UV exposed MAb-B43.13 since the native MAb-B43.13 appears to show a reduced response rate from Day 23 to Day 77. Actual values of increased response at day 77 are shown in Table 8.

Table 8

TOTAL AND AB₂ INDUCTION IN RATS INJECTED WITH NATIVE OR UV-EXPOSED MAB--B43.13

	TOTAL IMMUNE RESPONSE (mean ± S-E)	Ab₂ RESPONSE (mean ± S-E)
Native Mab — B43.13	38.47 ± 2.99*	18.77 ± 8.23
UV-exposed Mab — B43.13	1608.67 ± 369.39*	87.27 ± 45.11

n = 3

* p = 0.0496

Example 12. Protein modification as a result of UV exposure

The final chemical species present after photoactivation are specific for a given set of exposure conditions and the composition of the matrix solution (as described above). For simple polypeptides containing any of the three primary UV absorbing (UV-B) amino acids (cystine, tryptophan, tyrosine) the consequences of UV exposure can lead to amide bond cleavage, disulfide bond cleavage, alteration of absorbing amino acids and alteration of adjacent or close proximity amino acids. These changes are brought about by direct photoionization or photoexcitation and indirectly by radical formation from other constituents. The nature and extent of these

1 modifications is highly dependent on the chemical reactivities of the species
generated and other constituents reactive tendencies or stabilizing/quenching
capabilities. For this size of molecule any alteration generally results in dramatic
changes in biological function.

5 These same reactions can take place in larger proteins, however secondary and
tertiary structural elements present differing substrates for UV exposure in spite of
similar amino acid sequences. Therefore, the hydrophobic/hydrophilic nature and
proximal amino acids from distant chain sequences as a result of folding alter the
9 micro-environment and therefore influence the degree and nature of the modification,
in addition to other constituents issues stated above. Given the predominance of the
tryptophan absorption profile in this UV band width, it is thought to be the primary
site of the initial photoactivation process, but direct action on cysteine and tyrosine
are also viable.

13 The mechanism for indirect amino acid modifications has been proposed as
local hydrated electron generation or direct energy transfer from the primary
absorbing site. The primary observed changes for large proteins focus on measurable
chemical/biochemical changes such as absorption and fluorescence determinations of
17 aromatic amino acids which relate to global modifications. Individual amino acid
alterations be detected in this group of proteins where sulfhydryl content can be
determined as evidence of cysteine disulfide cleavage and/or where a critical amino
21 acid for function is involved. For smaller proteins amino acid hydrolysis and
complete quantitation can be performed. The primary concern for functional large
proteins, such as enzymes, receptor, or antibodies, is therefore not specific amino acid
modification but the consequences of any change on their biological function, and has
25 invariably been described as loss of enzyme function, receptor recognition, or antigen
binding.

29 **Example 13.** UV Exposed B43-13/CA125 antibody/antigen complex Produces
Better CA125 Specific Cellular immune Response and better humoral response.

Better cellular immune response was observed when the UV exposed antibody was presented in association with the antigen to T-cells. Thus, macrophages isolated from mouse peritoneal cavities were stimulated with native B43.13 or UV exposed B43.13 in association with CA125 and presented to CA125 specific mouse T-cells isolated from mice injected with CA125. Control experiments included stimulation of the macrophages without the antigen. When the proliferation of T-cells as monitored by [³H] - thymidine uptake was followed, optimal stimulation index was observed in macrophages stimulated with UV exposed B43.13 - CA125 complex. The results are summarized in Table 9 below.

Table 9

STIMULATING AGENT ¹	STIMULATION INDEX ²
CA125	2.76
Native MAb — B43.13	3.98
UV-exposed MAb — B43.13	3.31
Native MAb — B43.13 — CA125	4.71
UV-exposed MAb — B43.13 — CA125	5.28

1. 1 µg/ml of the antibody and 100 Units/ml CA125 were used.
2. Mean of three individual experiments done in triplicate.

Example 14. UV Exposure Conditions For Enhanced Immunogenicity Studies.

A typical experimental set-up consists of an eight lamp photoreactor unit (typically 200 -- 400 nm spectra, 90% at 300 +/- 20 nm; 3-9 watts/lamp) arranged concentrically about an approximately 15 centimeter diameter cylinder with appropriate associated electronics, shielding, etc. In this photoreactor unit (RMR-600, Southern New England Ultraviolet Company), samples to be exposed are arranged in several configurations: (1) as individual 1.5 ml (borosilicate glass or quartz) vials tubes located on an eight unit carousel (approx. 5 cm diameter) which is rotated in

1 the chamber at 1-5 rpm for 0-180 minutes (typically 30 minutes); (2) as 2 single
vial/tubes (as above) placed in the center of the exposure source and exposed for
similar time frames; or (3) as a helical glass (as above) coil (approx. 3 mm external
5 diameter) which allows target solution to flow through the photoreactor unit for
various time frames of approximately 0-180 minutes, but typically 10-20 minutes.
This latter set-up allows considerable volumes of target solution to be exposed on a
continuous basis for large-scale manufacturing purposes.

9 Under any of these exposure conditions, protein target solutions at 0.5-10
mg/ml (typically 5 mg/ml) in a variety of expected benign low molarity buffer
solutions (typically phosphate, pyrophosphate, or tartrate; pH 5-10), can be exposed
to determine their effects on target protein immunogenicity.

Example 15.

Three derivatives of scFv with additional C-terminal extensions containing
mouse and human tuftsin (pDL-6 and pDL-11), or a control sequence (pDL-10), were
designed. To construct plasmids pDL-6, pDL-10, and pDL-11, DNA
oligodeoxyribonucleotides

(5'-GAATTCTGGAGGTGGTACCCAGCCTAGGTAGC-3',

5'-GAATTCAGCTGGAGGTGGTGGATGTGC-3', and

5'-GAATTCTGGAGGTGGTACCAAGCCTAGGTAGC-3')

coding for the amino acid sequences N-SerGlyGlyGlyThrGlnProArg-C,

N-SerAlaGlyGlyGlyGlyCysAla-C, and N-SerGlyGlyGlyThrLysProArg-C, were used

by inserting fragments in *EcoRI* and *EagI* sites of pPIC-B43. The plasmid DNAs were
transformed into competent GS115 cells by electroporation and the resulting

transformants were selected on histidine-deficient media. All positive clones obtained
were isolated, cultured in induction media, and analyzed for protein expression in SD
S-PAGE followed by Commassie staining. The scFv-tuftsin proteins were produced
in minimal media to simplify some downstream protein purification process.

1 In order to evaluate the anti-idiotypic response, six to 8-week-old BALB/c
mice were immunized with 50 μ g scFv-tuftsins subcutaneously (Day 0). Two weeks later
the mice were received 25 μ g of scFv-tuftsins intraperitoneally. The serum of mice was
collected on Day 7, 14 and 21.

5 The anti-idiotypic antibody production was detected by enzyme-linked
immunosorbent assay (ELISA). Briefly, chimeric B43.13 was coated to a solid surface
and then blocked by 3% BSA/PBS. The chimeric B43.13 was incubated with serum
samples for 1 h and then incubated with goat anti-mouse H+L-HRPO for another
9 hour, followed by three washes with Tween 20/PBS. A color reaction was developed
by adding 50 μ l of substrate solution. Absorbance was read at 405nm. The same
procedure was applied to detect anti-anti-idiotypic antibody (Ab3) production except
CA125 was coated to ELISA plate at the beginning.

The data shows that it is possible to detect both Ab2 and Ab3 in the serum
samples and this indicates that scFv-tuftsins retained the idiotype immunogenicity
which could trigger humoral immune response in mice. We found that the mice
immunized with scFv-tuftsins started to show strong anti-idiotypic antibody (Ab2)
production after day 20 post the first immunization. However, the anti-anti-idiotypic
antibody (Ab3) production appeared earlier, peaking around day 15. This indicates
that the induction of an idiotype network response might be an important part of the
effector mechanism in MAb-based therapy.

Example 16. Construction and characterization of single chain antibody

25 The MAb B43.13 variable domain sequences were PCR-amplified using
sequence specific primers, and engineered into a cloning vector with scFv orientation
of V1-linker-Vh. The DNA fragment coding for the scFv was then sub-cloned into *P.*
pastoris vector, pPIC-9 with aF secretion signals, resulting in recombinant plasmid
pPIC-B43.13. One derivative of pPIC-B43.13 with additional C-terminal extensions
containing one cysteine (pDL10) was designed to form a disulfide bridge. Therefore,
29 the antigen binding activity can be enhanced by increase of avidity. To construct

1 plasmids pDL10, DNA oligodeoxyribonucleotides (5'-
GAATTCAGCTGGAGGTGGTGGATGTGC-3') coding for the amino acid sequences,
N-SerAlaGlyGlyGlyGlyCysAla-C were used by inserting fragments in *EcoRI* and *EagI*
sites of pPIC-B43.13.

5 The plasmid DNAs were transformed into competent GS115 cells by
electroporation and the resulting transformants were selected on histidine-deficient
media. After screening for integration at the correct loci, (i.e. colonies can grow on a -
his/+glycerol plate but grow slowly on a -his/+methanol plate), all positive clones
9 obtained were isolated, cultured in induction media, and analyzed for protein
expression in SDS-PAGE followed by Coomassie staining, as we described previously
(Luo et al., 1997). The protein samples were dialysed against PBS and concentrated
using Centricon® 10 filter (Amicon, Danvers, MA).

Purity of scFv-pDL10 were analyzed by SDS-PAGE under reducing condition.
CA125-binding specificity was determined using a ELISA in which microtiter plate
wells were coated with CA125, CA15.3 (a human breast cancer antigen), or CA19.9
(a human colon cancer antigen). The bound single chain antibody was detected by
peroxidase-labeled goat ant-mouse H and L (Southern Bio. Associ.) For 1 hour at
room temperature. Following three washes, 50µl of ABTS substrate solution was
added. The absorbance was measured at 405nm.

Single chain Fv containing poly(lactic-co-glycolic acid) microspheres were
prepared by a double-emulsion technique with some modifications (Uchida et al.,
1994). Na¹²⁵I labeled scFv-pDL10 was used as a tracer to determine the loading
efficiency. Briefly, scFv-pDL10 (1.5 mg) and Na¹²⁵I-scFv-pDL10 (0.4 µg) in PBS was
mixed with 500 µl of chloroform containing 100 mg PLGA 50/50 (Lactel). The mixture
25 was sonicated for 15 s using a sonicator homogenizer (Heat System, New York). The
resulting emulsion was added to 2 ml of 9% poly(vinyl alcohol) (PVA, Aldrich, USA).
Emulsification was continued by sonicate on for 1 min. The emulsion was transferred
to 8 ml of 9% PVA and stirred for 2 hours for evaporation of the chloroform.

1 Microspheres were recovered by centrifugation (15 min, 15000 rpm) and have washed
with distilled water and freeze dried for at least 24 hours.

 BALB/c female mice 6-8 weeks of age were used in all in vivo experiments.
The immunization groups included five groups: 1) immunized with PLGA
5 microspheres, 2) immunized with scFv-pDL10, 3) immunized with scFv-pDL10
formulated in PLGA microspheres, and the other two groups immunized with the
mixture of formulated scFv-pDL10 and GM-CSF or TNF- α . After collection of pre-
immune serum samples, groups of 4 mice received two subcutaneous immunizations
9 on day 0 and day 14, followed by two intraperitoneal immunizations on day 21 and
day 28. The dose for immunization was 10 mg of the microspheres for s.c., 5 mg for
i.p.. For the other groups that received no microspheres, the dose of scFv-pDL10
matched the amount formulated. The cytokines were purchased from R & D Systems
(USA) and were given to mice at a dose of 0.1 μ g per day. Tail vein blood samples
were taken periodically into Microtainer tubes (Becton Dickinson, USA) and frozen at
-80°C until assay.

13 Example 17 . Dose

 Those with skill in the art recognize that the administered dosage can vary
widely based on a wide set of different circumstances. The following provides
preliminary dosage guidelines.

21 Retrospective analysis of more than 100 patients who have been injected up to
ten times with a 2mg dose of MAb-B43.13 indicated that some of these patients
experienced: a) an unusual course of their disease, characterized by unexpectedly
long survival times; and b) no significant adverse reaction or toxicity.

25 Immunological studies were conducted to understand and evaluate the *in vivo*
mechanism of action of MAb-B43.13. These studies indicated that the extent of anti-
idiotypic induction in patients injected with a 2mg dose of MAb-B43.13 was unrelated
to the number of injections or the clinical stage of their disease. However, anti-
29 idiotypic induction is dependent on the levels of the circulating CA 125 present in the

1 patient's sera. Additional experiments demonstrated that the injection of MAb-B43.13
into patients with measurable serum CA 125 led to the formation of antigen-
antibody complexes, resulting in antigen epitope presentation and antigen-specific
humoral and cellular response to the tumor.

5 These studies indicate that an effective dose requires only enough antibody to
optimally deliver and present all possible circulating CA 125 antigen to the immune
system. *In vitro* studies indicated that 1 ng of MAb-B43.13 can bind 10 units of CA
125. Assuming 40 mL of plasma per kg of body weight, the injection of 2 mg of
9 MAb-B43.13 into a 60 kg patient can bind approximately 8333 U/mL of CA 125 in
serum. Since all of the ovarian cancer patients tested to date have had far less than
8333 U/mL of CA 125 in their serum, an injection of 2 mg of MAb-B43.13 is more
than sufficient to induce the required immune response. CA 125 levels were
considered as significantly elevated when the CA 125 concentration is above three
times the cut-off level (e.g., 3 x 35 U/ml, or 105 U/ml). Additionally, in patients that
received radiolabeled MAB-B43.13 for immunoscintigraphic confirmation of the
disease, the results of imaging were excellent in spite of high serum CA 125,
suggesting that there is excess MAB-B43.13 for specific tumor uptake.

Furthermore, multiple injections at selected intervals appear to provide optimal
benefits to patients, since CA 125 is generated throughout the course of the disease.

Finally, the retrospective analysis showed that the 2 mg dose appears to have
therapeutic efficacy; none of the patients (>100) have developed any serious side
effects or adverse reactions. If the total HAMA response is an indication of anti-
idiotypic induction, a 2 mg dose generates significant levels of anti-idiotypic
antibodies to produce the desired therapeutic benefit. Multiple injections of 2 mg of
25 MAb-B43.13 at selected intervals appears to maintain the anti-idiotypic antibodies at
the desired therapeutic level without causing any isotypic HAMA-induced toxicity.

A range of effective doses or a therapeutically acceptable amount of MAb-
B43.13 therefore includes, but is not limited to, a total dose of about 2 mg or less.

Example 18 . Immunophotodynamic therapy

An immune competent mouse model is available for the MUC-1 system. The MUC-1 transfectant 413 BCR forms tumors (subcutaneous or intravenous) in BALB/c or CB6F1 mice. The BALB/c animal model was used to test HBBA-R2-SL, HBBA-R2 SIL with Alt-1 and a control antibody (HBBA-R2 is a hypocrellin B derivative described in PCT/US98/00235, incorporated herein by reference; SL = stealth liposome; SIL = stealth immunoliposome). The model has the advantage that the bystander effect of the immune system can be analyzed. Help from the immune system, especially from macrophages, has been reported to augment the immune system for the outcome of PDT and as necessary for obtaining complete response rates. BALB/c mice were injected with $2-2.5 \times 10^6$ 413BCR cells into the right flank (s.c.).

Tumors appeared after 7-10 days. When tumors reached a diameter of about 5 mm, hypocrellin formulations were injected iv. at 1 mg/kg. Two hours post injection of HBBA-R2, light treatment was performed at 40 J/cm^2 ($>600 \text{ nm}$). Mice were followed by measuring tumor size. When tumor size reached 4-times pre-treatment volume, mice were sacrificed. Tumors were followed for 2 months and survival curves were calculated, plotted and compared to the light-only treatment group.

For stealth immunoliposome compositions, the antibody Alt-1, which binds to 413BCR cells, was used. Tumors were measured every second day in three dimensions. When tumors reached 4 times pre-treatment volume, mice were sacrificed. Mice treated with light only or drug only were used as control.

Immunoliposomes with Alt-1 showed complete cure in the presence of light. The HBBA-R2-SIL [Alt-1] also showed improved survival in the dark, compared to mice treated with light only. These results suggest a therapeutic effect of Alt-1 in this model and underline the importance of combined therapy using PDT and antibody vaccine.

For all formulations tested, immunoliposomes specific for the tumor showed the best therapeutic effect. This was also reflected when tumor volumes were used

1 for comparison. The reason for the enormous differences between SL and SIL is not
yet completely understood. The data suggest that immunoliposomes might cause an
immune response in BALB/c mice that can help killing the tumor. From the
biodistribution data we know that HBBA-R2 uptake at the tumor is slightly higher
5 with SIL compared to SL.

Example 19 .

9 The murine monoclonal antibody Alt-4 is a candidate for the development of
an anti-gastrointestinal cancer compound. MAb-Alt-4 binds to tumor antigen CA19.9,
a Sialyl Lewis^a antigen which is now generally recognized as one of the most
important tumor-associated markers for gastro-intestinal cancer. An approach of
chimerization of antibody is to construct mouse-human antibody, which is composed
of mouse variable region and human constant region, by using recombinant DNA
technology. Most reports demonstrate the chimeric antibody is able to retain the same
specific binding activity to the antigen as its parental mouse antibody, but avoid the
human anti-mouse antibody (HAMA) response with *in vivo* applications.

Experimental Strategies:

cDNA isolation of V-genes: RT-PCR experiments were carried out to isolate
antibody variable genes using specific primers. The cDNAs were then cloned into
cloning vector pBluscript for DNA sequencing.

21 Chimeric Antibody Construction: chimeric clones of PAH-18.4H8PCRII#8 and
PAG-18.4L20PCRII#19 was obtained by ligating PAG4622-18.4LPCRII and PAH46.6-
18.4HPCRII as expression vectors and inserts were obtained from PBKS-
18.4L20PCRII#14 and PBKS-18.4HPCRII #19. Chimeric clones were used for
25 transfection of SP2/0 cells. To obtain the most efficient method for co-transfection of
these cells control plasmid pSV- β gal DNA was used as a positive control plasmid to
obtain the optimal conditions for transfection into cells.

1 Transfection: both methods of transfection showed successful transfection
efficiency. Lipofectamine causes some cell death but most cells (80%) of cells that stay
alive are transfected. In electroporations method cells transfection efficiency was high
and cells that were transfected were growing into colonies which contained the new
5 control plasmid. After establishing optimal conditions for transfection of SP2/0 cells
co-transfection of SP2/0 cells with PAH-18.4 and PAG-18.4 was done.

Lipofectamine method: 2ug of each DNA plasmid was used. The same
protocol was mentioned above was followed. 24 hours after transfection, cells were
9 harvested from 6-well plates and cells were seeded in 96-well plates with cell density
of 1.0×10^4 cells/well. After overnight incubation at 37°C , selection media was added
to each well in 1:1 ratio. Selection media includes $1 \mu\text{g}/\mu\text{l}$ of mycophenolic acid and
5mM histodinal, 7.5 PH which was adjusted using NaOH. Selection media was
changed every 3 days and cells were in selection media for 12 days

Electroporation method: 20 μg of each DNA plasmid was used. The same
method as mentioned above was used for transfection. Cells were plated into 96-well
plates after electroporation. with 1×10^4 cells/well density. 24 hours after
transfection selection media was added to cells. Cells were kept under selection
media for 12 days and media was changed every 3 days.

To determine whether transfection has occurred supernatant of transfected
cells were used for ELISA to assay the production of desired chimeric protein. CA
19.9 was used to coat the plates and they were blocked by 3% BSA. For primary
antibody tissue culture supernatant was used and for secondary antibody rabbit anti
human (Fab'2) IgG (H +L) was used. Assay from ELISA gave positive results for
production of desired product.

25 **Example 20** . Experimental Verification Of The Generation Of Antibody
Response Against Multiple Epitopes Present In An Antigen By Injecting An
Antibody Against A Single Epitope

1 Cancer antigen CA125, which is expressed on more than 80% of epithelial
ovarian cancers, is used as an example to demonstrate the present invention.

CA125 has multiple epitopes recognized by different antibodies such as OC125,
M11, B43.13, B27.1, among others. In the present invention, MAb-B43.13 was used to
5 generate a CA125 specific immune response which included recognition of the B27.1
epitope.

Method: 86 ovarian cancer patients with active disease were tested for the presence
9 of antibodies against CA125. None of the patients had antibodies against CA125
before injection of MAb-B43.13. The patients were injected with 2 mg of MAb-B43.13
at varying time intervals (e.g., see Table 5 for some of the patients). Sera from these
patients were analyzed for the presence of human anti-CA125 antibodies by their
ability to bind to the CA125 [R. Madiyalakan et al, *Hybridoma*, 14:199-203 1995]].
Such anti-CA125 antibodies were further classified to be against the B43.13 epitope or
B27.1 epitope by their ability to inhibit the corresponding antibodies. The rationale
for the classification comes from the fact that anti-CA125 antibodies in these patients
would have been generated by either of the following two pathways:

1) If the anti-CA125 antibodies were generated in the manner suggested by
the network theory noted above, the pathway would follow $Ab1 \rightarrow Ab2 \rightarrow Ab3$.
21 Following this scheme, MAb-B43.13 (Ab1) would generate an anti-idiotypic against
MAb-B43.13 (Ab2), which would in turn generate an anti-anti-idiotypic against MAb-
B43.13 (Ab3; or anti-CA125 antibody). Furthermore, the Ab3 antibodies generated
under this pathway would bind and be inhibited only by MAb-B43.13, because the
25 B43.13 epitope is the only epitope present.

2) If the anti-CA125 antibodies were generated in a manner suggested by
the present invention, the pathway would follow $Ab1 + \text{soluble antigen} \rightarrow Ab3'$.
29 Following this scheme, MAb-B43.13 (Ab1) would bind the CA125 serum antigen,

1 which would in turn generate an anti-CA125 antibody (Ab3'). Furthermore, the Ab3'
antibodies generated under this pathway would bind and be inhibited by B27.1
antibodies, because, as noted above, CA125 is multi-epitopic and B43.13 and B27.1
epitopes are distinct; also, Ab3' will not bind to anti-MAb-B43.13 antibodies.

5 Thus, if the patients serum contained anti-CA125 antibodies that were
inhibitable by MAb-B43.13 only, it was classified as containing Ab3; those inhibitable
by MAb-B27.1 were classified as Ab3'.

9 Results

Fourteen patients developed anti-CA125 antibodies in their sera (Table 1) in
response to MAb-B43.13 injection. 10 of these 14 patients had Ab3' while only two
patients had Ab3 antibodies in their sera. Two patients also had both the antibodies.
The presence of Ab3 in their sera was also confirmed by the ability of these
antibodies to bind to the purified rabbit anti-MAb-B43.13 antibody. There were two
patients (#2 and #7) who had anti-CA125 antibodies, but were not inhibitable by
MAb-B43.13 or MAb B27.1, thereby suggesting that they may have antibodies against
CA125, which recognizes epitopes other than B43.13 or B27.1.

These results clearly indicate that when an antibody against a single epitope
(B43.13) was injected into a patient an antibody response against the whole antigen is
generated which recognizes different epitopes present in the antigen. The presence of
Ab3 in some patients could be explained by the likely presence of excess B43.13
epitope in the CA125 due to insufficient binding of the antibody to that epitope or
idiotype induction through Pathway I. Nevertheless, the predominant mechanism of
the response seems to be through Pathway II. In other words, injecting a monoclonal
antibody to a soluble multi-epitopic antigen into a patient having a functioning
immune system generates an antibody to the antigen, where the generated antibody
is inhibited by antibodies to different epitopes.

Example 21 .

In pharmaceutical studies, blood samples were analyzed for CA125 levels before and at selected intervals after MAb-B43.13 injection. In patients with elevated CA125 levels before injection, a significant drop in circulating CA125 levels could be seen immediately after MAb-B43.13 injection (Table 10). This clearly demonstrated that the binding agent upon introduction into the body interacts and removes the circulating CA125.

TABLE 10: CA125 Clearance after MAb-B43.13 Injection

Patient # (CA 125 levels are given in U/mL)

	002	003	004	006	007	008	010
Time (min) after MAb							
0	760	68	65	72	90	269	431
30	210	2	7	21	16	47	141
60	144	3	0	22	16	60	79
240	240	0	0	11	15	52	97
1440	277	5	3	6	23	59	96
2880	404	-	5	1	23	67	93
4320	429	-	7	-	-	-	-

Furthermore, antigen complexed with antibody is presented efficiently to the immune system and generates better antigen-specific humoral and cellular response. This was demonstrated by the following experiments shown in Examples 22 and 23.

Example 22 .

Balb/c mice were immunized either with 10 µg of MAb-B43.13 in PBS, i.v.;

10,000 units of CA125 in PBS, i.v.; or 10 µg of MAb-B43.13 and 10,000 units of CA125 in PBS, i.v., every three weeks for a total of 3 injections. The ratio in the B43.13/CA125 injection was similar to that observed in patients with elevated CA125 levels as determined based on the pharmacokinetics data given in Table 10. When the mice sera were analyzed for anti-CA125 antibody levels, the mice injected with the antigen-antibody complex had the highest titre. This supports the observation that binding agent - antigen interaction leads to better antigen specific humoral immune response compared to binding agent or antigen alone.

Example 23 .

Similarly, better cellular immune response was observed when the binding agent was presented in association with the antigen to the T-cells. Thus, macrophages isolated from mouse peritoneal cavities were stimulated with MAb-B43.13 alone; CA125 alone, a MAb-B43.13-CA125 complex; or control MAb-CA125 and presented to CA125 specific mouse T-cells (isolated from mice injected with CA125). When the proliferation of T-cells as monitored by [³H]-thymidine uptake was followed, optimal stimulation index was observed in macrophages stimulated with antibody-antigen complex (Figure 2).

Example 24 .

The role of serum antigen in inducing multi-epitopic antibody response as a consequence of an antibody injection was further confirmed in rabbit studies. Rabbits that do not contain any serum CA125, when injected with MAb B43.13, produced anti-CA125 antibodies that were not inhibitable by B27.1. In contrast, ovarian cancer patients with high serum antigen CA125 levels produce anti-CA125 antibodies that are inhibitable by B27.1 in response to MAb-B43.13 injection.

1 **Example 25 . Experimental Verification Of Induction Of Antigen Specific Anti-**
Tumor Response By Antibody Injection

Human anti-CA125 antibody causes tumor cell lysis through antibody dependent cellular cytotoxicity ("ADCC"). Although the injected MAb-B43.13 does not cause by
5 itself an ADCC and/or complement dependent cytotoxicity ("CDC") mediated lysis of ovarian tumor cells, the generation of anti-CA125 antibodies in patients injected with MAb-B43.13, leads to tumor cell lysis (see Figure 3). This was studied in a
11 ⁵¹Chromium release assay by incubating the labeled ovarian tumor cells with effector
9 cells, and sera of six patients injected with MAb-B43.13. This supports the conclusion that the injection of a binding agent leads to its interaction with the antigen, with a specific humoral response resulting in anti-CA125 antibodies that cause tumor cell lysis through ADCC. The results clearly demonstrated the generation of antigen specific anti-tumor response after injection of the antibody.

17 **Example 26 .**

Tumor killing either through an anti-CA125 antibody-mediated ADCC mechanism or through CA125-specific CLTs, lead to increased survival in patients injected with MAb-B43.13. Although high levels of serum CA125 have been suggested to be a poor prognostic indicator, they seem to have a beneficial effect in combination with the injection of anti-CA125 antibody in such patients. For example,
21 when the CA125 levels were more than 100 units/mL, immune response against CA 125 increased by more than 20% which in turn increased the median survival in those patients from 39.1 months to 54.5 months (Table 11). Thus the injection of a binding agent to a patient containing elevated levels of multiepitopic soluble antigen leads to
25 antigen specific humoral and cellular response which in turn leads to tumor killing followed by improved survival.

TABLE 11: Correlation between Serum CA125 Levels, Human Anti-CA125 (Ab₁) Response and Survival in Patients Injected with MAb-B43.13

Preinjection Serum CA125 Level	%-age of Patients with Human Anti- CA125 Response	Mean Survival in Month
<100 U/mL	10.3%	39.1
>100 U/mL	32.6%	54.5

Example 27.

One pancreatic cancer patient diagnosed with metastatic disease was repeatedly injected with a composition including an anti-CA 19.9 antibody. The patient received no other treatment, and survived for 22 months after the original diagnosis (19 months after surgery and the injection) This is compared to the current survival period estimate of six months survival after initial diagnosis.

While the present invention has been described in some detail by way of illustration and example, it should be understood that the invention is susceptible to various modifications and alternative forms, and is not restricted to the specific embodiments set forth. It should be understood that these specific embodiments are not intended to limit the invention, and the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention.

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